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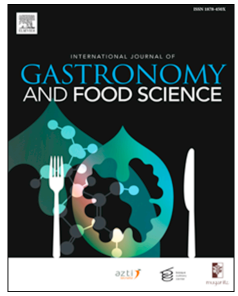

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Beyond the plate: How visual-affective environmental cues and physiological arousal drive food choice and sensory enjoyment in multisensory dining

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Abstract

This study investigated how visual-affective environmental cues influence food choices, physiological responses, and sensory experiences during a multisensory dining experience. A total of 360 adult participants were randomly assigned to consume a standardized meal consisting of various nutrient-dense (vegetables, cherry tomatoes, yoghurt) and energy-dense (pizza, fries, ice cream) foods. Participants ate while viewing one of five digital video environments or a silent control. The environments varied significantly in their affective properties, ranging from calm nature scenes to high-arousal urban and stressful contexts. Results indicated that calm, low-arousal videos elicited positive emotions (contentment), significantly increasing the intake and enjoyment of healthier food options, while reducing post-meal hunger and enhancing post-meal fullness and satiation. Conversely, highly stimulating environments, whether positive (excitement) or negative (distress), triggered elevated heart rate and skin conductance, leading to increased consumption of energy-dense foods. A Bayesian Network (BN) was employed to model the probabilistic dependencies between these variables. The present findings suggest that physiological arousal may represent an important regulatory mechanism linking environmental cues to eating behaviour, influencing unhealthy intake via two distinct mechanisms: a liking mediated hedonic route associated with excitement and a direct stress eating route associated with distress. Specifically, the presence of distress increased the probability of high unhealthy intake to 73 % independent of hedonic liking. These findings indicate that physiological arousal may be one pathway through which emotionally distinct video stimuli influence dietary decisions. More broadly, the findings raise the possibility that low-arousal dining environments may support more mindful and healthier eating patterns by reducing physiological arousal, although this implication requires direct testing in real-world settings.

Keywords: Multisensory dining, gastronomic experience, visual-affective cues, sensory enjoyment, hospitality design, Bayesian network.

1. Introduction

Eating behaviour in gastronomy is influenced by more than just the food on the plate; the surrounding environment dynamically shapes perception, emotion, and consumption. Features of the dining space, including visual atmosphere, sound, and spatial design, have been shown to alter food evaluation, intake, and satiety responses (Biswas, Szocs, Chacko, & Wansink, 2017; Wansink, 2004; Wansink & van Ittersum, 2012). These findings highlight the role of external cues in shaping the gastronomic experience beyond intrinsic food attributes.

These environmental effects are mediated by emotional and sensory processes. Context-induced emotions can modify taste perception and food evaluation, as demonstrated by increased sweetness, creaminess, and flavour perception in familiar settings (Kantono, et al., 2018), and enhanced positive affect and sweetness perception in more engaging contexts (Xu, Hamid, Shepherd, Kantono, & Spence, 2019). These findings indicate that both calming and arousing environments influence affective experience and sensory judgement, which may ultimately affect consumption.

Environmental contexts can be characterised along dimensions of valence and arousal, ranging from calm, low-arousal settings to highly stimulating or war-related contexts stressful environments (Montanari, Wang, Birenboim, & Chaix, 2024; Gulich, Fedorova, Petrenko, Vepsäläinen, & Erkkola, 2025). In modern gastronomy, digitally mediated and immersive virtual environments produce similar emotional and sensory effects, with immersive contexts enhancing engagement and ecological validity (Long, Masters, Sajjadi, & Masterson, 2023; Curi Braga, et al., 2025). For example, viewing beach scenes with multisensory cues increased positive emotions and the desire for cooling foods (Liem, Mawas, & Keast, 2023), while a virtual ‘sunny picnic’ enhanced food enjoyment compared to a ‘rainy picnic’ that induced loneliness and worry (Pennanen, Närväinen, Vanhatalo, Raisamo, & Sozer, 2020). Collectively, these findings confirm that environmental cues, whether physical, auditory or visual, dynamically shape emotions and eating behaviour.

In addition to affective properties, the dynamic characteristics of visual stimuli may influence engagement and physiological arousal. Moving scenes increase immersion and activation through temporal and spatial variation, whereas static scenes promote attentional stability (Wang & Suh, 2021). Despite this, the role of visual motion in eating contexts remains underexplored, particularly given the increasing prevalence of immersive, screen-based elements in modern hospitality design.

Existing research shows that environmental stimuli influence both food perception and consumption. Low-arousal, positive environments are associated with enhanced enjoyment and more health-oriented eating, whereas high-arousal contexts promote indulgent consumption of energy-dense foods (Biswas, Szocs, Chacko, & Wansink, 2017; Snyder, 2021). Dynamic visual cues may further enhance perceived taste (Li & Liu, 2022) , while high arousal increases sensitivity to unpleasant flavours ((Spinelli, Dinnella, Prescott, & Monteleone, 2023; Prescott & Spinelli, 2024), and negative emotional states are linked to emotional eating (Ha & Lim, 2023). However, few studies have examined how video-based visual-affective contexts differing in valence and arousal influence hedonic responses and food intake, particularly when such contexts also vary in broader visual characteristics such as scene dynamics and movement.

Despite growing evidence that environmental cues influence eating behaviour, important gaps remain in understanding the mechanisms underlying these effects. Previous studies have largely focused on isolated outcomes, such as food perception, emotional responses, or food intake, without simultaneously examining how environmental characteristics, physiological arousal, emotional states, and hedonic responses interact to influence healthy and unhealthy eating behaviours. Furthermore, few studies have employed probabilistic modelling approaches capable of capturing these complex relationships.

To address these gaps, the present study integrates subjective, physiological, and behavioural measures to examine how visual-affective environmental cues are associated with food intake. A Bayesian Network (BN) approach was applied to model probabilistic dependencies among physiological arousal, emotional states, and dietary outcomes (Jensen, 1996; Korb & Nicholson, 2010; Murphy, 2002). This approach enables the examination of complex, non-linear relationships within a Stimulus–Organism–Response framework.

To clarify this, we have mapped the seven emotion descriptors utilized in our analysis to their approximate theoretical positions on the valence-arousal circumplex (Table 1) (Posner, Russell, & Peterson, 2005). Accordingly, this study investigates how visual-affective environments differing in valence, arousal, and motion are associated with food intake. It was hypothesised that:

Table 1 Breaks down the seven emotions based on their theoretical positions on the valence-arousal circumplex for you to use:

Emotion Group	Descriptor	Arousal (Activation) Level	Valence (Pleasantness) Level

Excitement	Active	Peak High Arousal	Neutral to Mildly Positive
Excitement	Excited	High Arousal	Moderately Positive
Excitement	Enthusiastic	Moderate-High Arousal	Highly Positive
Contentment	Happy	Neutral Arousal	Peak Positive
Contentment	At ease	Low-Moderate Arousal	Highly Positive
Contentment	Relaxed	Low Arousal	Moderately Positive
Contentment	Quiet	Peak Low Arousal	Neutral to Mildly Positive

H1. Higher physiological arousal will be associated with increased probability of high-arousal emotional states (excitement, distress) and decreased probability of low-arousal positive states (contentment), and with increased energy-dense (unhealthy) food intake. independent of liking.

H2. High-arousal positive states (excitement) will be associated with increased unhealthy food liking and intake.

H3. High-arousal negative states (distress) will be directly associated with increased unhealthy food intake.

H4. Low-arousal positive states (contentment) will be associated with increased liking and intake of low energy-dense (healthy) foods.

H5. Low-arousal negative states (boredom) will be associated with reduced healthier food options through reduced sensitivity to internal appetite cues.

Material and Methods

2.1. Participants

A total of 360 adults (185 males, 175 females; Mage = 35.09 years, SD = 8.64) were recruited from a university population and randomly assigned to one of six experimental conditions. A power analysis conducted a priori determined that the sample size provided sufficient power (0.90 - 0.95) to detect a large effect size (Cohen's $d = 0.8$), as detailed in Appendix A.*1*. Ethical approval was obtained (AUTEC: 19/289), and all participants provided informed consent.

2.2. Selection of Food Types

Food items were selected from a larger pool of commonly consumed lunch foods that included both healthy and unhealthy options. Six lunch items were selected to represent healthy and unhealthy categories based on perceived healthiness ratings from a preliminary pilot study (Appendix A. *2*). The foods selected for the study's analysis were classified based on objective Energy Density (kcal/g) using the Volumetrics framework (Rolls, 2000). Foods are classified by calculating their energy density, which is obtained by dividing the calories per serving by the serving weight in grams. Although the Volumetrics framework objectively classified the items as either 'low' (0.18–0.99 kcal/g) or 'medium' (2.33–3.41 kcal/g) energy density, the terms 'healthy' and 'unhealthy' are utilized throughout this paper. Detailed descriptions of food items, including brands, portion sizes, nutritional values, and energy density are provided Appendix A. *2*

2.3. Selection of Video Stimuli

Five video clips were selected for the main experiment based on their distinct affective profiles identified during the stimulus-validation stage, with the aim of representing a range of visual-affective contexts differing primarily in emotional valence (positive to negative) and arousal (low to high). Selection was guided by the emotional distinctiveness of the clips, together with their suitability for use in the eating experiment. The selected stimuli represented a range of calm, stimulating, and stressful contexts, including scenic, social, urban, and wartime settings. Although the clips also differed in the degree of visual movement (e.g., camera motion and scene dynamism), motion was not manipulated as an independent orthogonal factor in the present design. Rather, it was treated as one descriptive characteristic of the broader visual-affective context represented by each clip. Detailed descriptions of the clips and their affective characteristics are provided in Appendix A. 3.

The selected clips were drawn from pre-existing video material and therefore differed in native duration. To ensure comparability across conditions, presentation time was standardised during the experiment by repeating shorter clips as needed so that each participant received the same assigned video context throughout the viewing period.

2.4.Emotion ratings

Self-reported emotions were collected from participants following the consumption of the standardised meal and exposure to their assigned environmental condition using a Check-All-That-Apply (CATA) method with 12 emotion descriptors selected from the Consumer Emotion Questionnaire (CEQ; Jaeger et al., 2020) were excited, happy, relaxed, at ease, enthusiastic, quiet, bored, unhappy, tense, nervous, active, and uninspired. These descriptors were selected from the CEQ because they cover a broad range of human emotional experiences based on the circumplex model of affect, representing different combinations of valence (pleasant–unpleasant) and arousal (high–low activation) (Jaeger et al., 2020). The CATA methodology has been widely validated for measuring consumers' emotional responses to food and environmental stimuli (Ares et al., 2015; Gunaratne et al., 2019). To minimise order effects, the presentation of descriptors was counterbalanced across participants as described inPre-Test correspondence analysis (CA) (video selection) (Appendix A.*5*.

2.5. Subjective measurements of hunger, fullness and satiation

Subjective ratings of hunger, fullness, and satiation were assessed using 10-cm visual analogue scales (VAS; Flint et al., 2000). Hunger represented the subjective desire to eat. Fullness referred to the physical sensation of stomach distension following food consumption, whereas satiation represented the subjective feeling of having eaten enough and no longer wishing to continue eating. Each scale ranged from 0 to 10, with anchors defined as follows: hunger (0 = “Not at all hungry”, 10 = “Extremely hungry”), fullness (0 = “Not at all full”, 10 = “Extremely full”), and satiation (0 = “I am completely empty”, 10 = “I cannot eat another bite”). Measurements were obtained immediately before the meal and immediately after the meal, corresponding to the periods prior to and following exposure to the assigned environmental video clip.

2.6. Food pleasantness, liking and enjoyment measurements of food items

Food pleasantness, overall liking, and enjoyment of the food items were assessed post-consumption under each experimental condition using 10-cm unstructured visual analogue scales (VAS), following established sensory and appetite research (Blundell et al., 2010; Andersen & Hyldig, 2015). Pleasantness was defined as the immediate sensory appraisal of how pleasant the food was perceived to be. Overall liking represented the participant's overall evaluative judgement or preference for the food after considering the entire eating experience. Enjoyment reflected the degree of pleasure experienced while consuming the food. Although these measures are related, they capture different aspects of hedonic evaluation and were therefore assessed separately to provide a more comprehensive assessment of participants' food responses (Blundell et al., 2010; Andersen & Hyldig, 2015). Each attribute was rated on scales anchored from 0 (extremely negative) to 10 (extremely positive), with higher scores indicating more favourable hedonic evaluations.

2.7. Electrophysiological measures

Electrophysiological data were recorded using a NeXus-10 MK-II multimodal acquisition system, including skin conductance (SC), heart rate (HR) derived from electrocardiogram (ECG), and blood volume pulse (BVP) amplitude, using BioTrace+ software (Version 2018A; Mind Media BV, Netherlands) (Van der Zwaag et al., 2011).

SC, ECG, and BVP signals were collected using standard electrode placements and a three-lead ECG configuration (Lead II). Heart rate was calculated from R–R intervals, and BVP amplitude was used as an index of peripheral blood flow.

Recording began with a five-minute baseline period, followed by video exposure during which participants remained seated and minimised movement. Headphones (Sennheiser HD 518) were used to standardise audiovisual presentation.

2.8. Experimental procedure

The study employed a between-subjects design and was conducted in a purpose-built sensory laboratory. Participants were seated in individual cubicles and randomly assigned to one of six conditions: a silent control or one of five environmental video conditions differing in affective properties and visual motion.

All sessions were conducted between 11:00 am and 3:00 pm and lasted approximately 60 minutes. Participants were instructed to consume a light meal 1–2 hours prior to testing. Upon arrival, written informed consent was obtained, anthropometric measures were recorded, and participants completed the Dutch Eating Behaviour Questionnaire (DEBQ).

Electrophysiological sensors were then attached and tested, followed by a 5-minute baseline recording under neutral conditions. Participants subsequently viewed their assigned video clip for 5 minutes while physiological data were recorded, after which they completed pre-meal ratings of emotion, hunger, fullness, and satiation. A brief rest period preceded the eating task.

During the ad libitum eating task, participants consumed a standardised meal consisting of three healthy and three unhealthy food items, accompanied by 350 mL of water, while the assigned video continued to play. Participants were allowed up to 30 minutes to eat and could stop at any point once comfortably full.

Immediately post-consumption, participants completed emotional ratings using the Check-All-That-Apply (CATA) method, followed by ratings of hunger, fullness, and satiation, pleasantness, enjoyment, satisfaction, overall liking, and perceived healthiness of the food items.

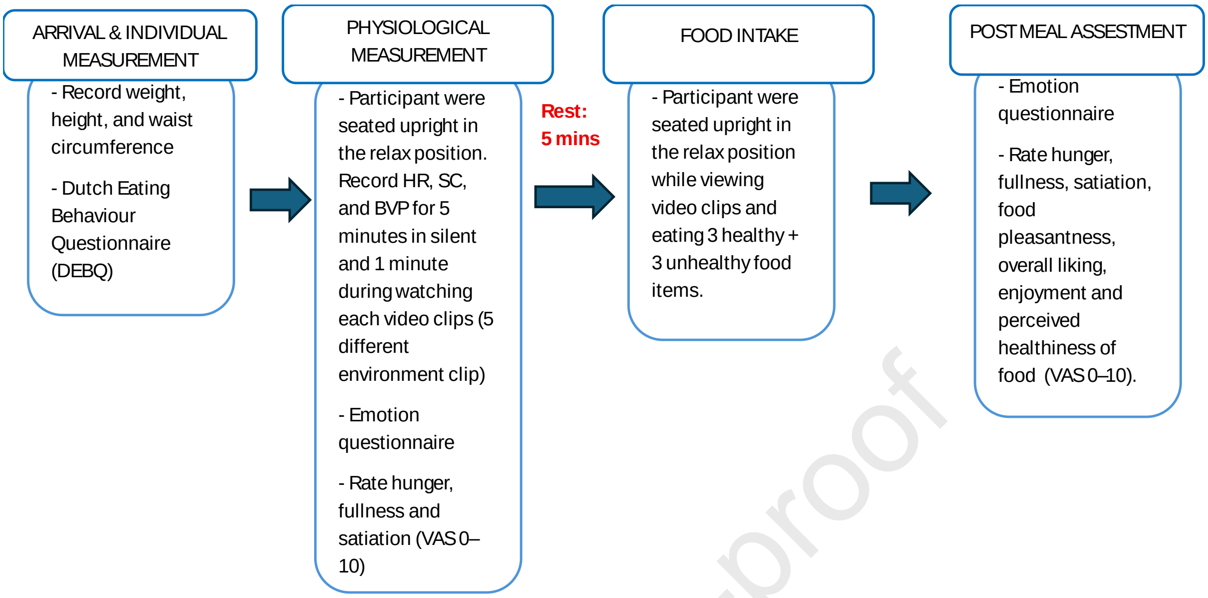


Figure 1. Study Procedure

2.9. Statistical Analysis

2.9.1. Emotion

Emotion ratings were dichotomised (0 = not selected, 1 = selected) and Cochran's Q test used to compare the frequency of emotional responses across the silent and video conditions (XLSTAT, Version 2021.5; Addinsoft, USA). For tests showing statistical significance ($p < 0.05$), multiple pairwise comparisons were performed using the Marascuilo procedure. To explore associations between emotions and eating conditions, cosine values (range −1 to 1) were calculated for each attribute (Lin et al., 2022), where absolute cosine values below 0.707 indicate no meaningful relationship (Carr et al., 2009).

2.9.2. Electrophysiological measures

To standardise the measurements, average change values of the electrophysiological parameters were calculated for each individual, including skin conductance level (SCL), heart rate (HR; extracted from the ECG), and blood volume pulse (BVP) amplitude. The individual 5-minute quiet baseline was used as the reference condition. Following Shepherd et al. (2025), the percentage change from baseline was calculated using the following formula:

Percentage change (%) = ((raw value − mean baseline value) / mean baseline value) × 100.

Subsequently, a multi-way ANOVA was conducted on the transformed data, with video condition (including silence) specified as a within-subject factor and electrophysiological parameters (SCL, HR, and BVP amplitude) treated as dependent variables. Greenhouse–Geisser corrections were applied when the assumption of sphericity was violated. Where significant main effects or interactions were observed, Tukey's HSD *post-hoc* tests were performed to determine pairwise differences between conditions.

2.9.3. Visual analogue scales (VAS)

Ratings of hunger, fullness (reverse-scored), and satiation were assessed using visual analogue scales (VAS), with change scores calculated as pre-meal minus post-meal values ($VAS_{pre} - VAS_{post}$). Post-meal pleasantness, food liking, and satisfaction ratings were calculated by averaging scores across healthy and unhealthy food items. Multi-way ANOVA was used to examine hunger, fullness, satiation, pleasantness, food liking, and satisfaction scores across video conditions. *Post hoc* Tukey's honestly significant difference (HSD) tests were applied when significant effects were observed ($p < .05$).

2.9.4. Multiple Factor Analysis (MFA)

Multiple Factor Analysis (MFA) was performed using XLSTAT (Version 2025; Lumivero, USA). MFA enables the simultaneous analysis of multiple data sets to explore relationships between observations and variables. In this study, MFA was used to examine how the different eating conditions influenced emotional responses, food intake, and liking of food items.

2.9.5. Bayesian Network (BN) Analysis

A discrete Bayesian Network (BN) was constructed to examine the hypothesised Stimulus–Organism–Response (S–O–R) pathways (H1–H5). The network was informed by a valence–arousal framework, with four discrete emotional nodes representing affective states: Excitement (high arousal, positive valence), Contentment (low arousal, positive valence), Distress (high arousal, negative valence), and Boredom (low arousal, negative valence).

The model captured probabilistic dependencies among physiological arousal, emotional states, and dietary outcomes (healthy intake, unhealthy intake, and satiety). Physiological arousal was specified as an antecedent variable in the Bayesian Network, meaning that it was modelled as an earlier factor capable of influencing emotional states and food-related outcomes. Additional direct links to unhealthy intake, including a pathway via distress, were included to test stress-related eating (Figure 5).

Continuous variables were discretised into three levels (low, medium, high) prior to analysis. The BN was implemented in Python using *pgmpy* and *NetworkX*, with structure learning based on a score-based hill-climbing algorithm optimised using the Bayesian Information Criterion (BIC) (Cosic, 2021; Nagarajan et al., 2013). Structural constraints were applied to maintain S–O–R directionality.

3. Results

3.1. Participants characteristics

Physical (age, BMI, waist circumference) and psychological characteristics (DEBQ dimensions) were included as covariates in all analyses. No significant effects of age, waist circumference, BMI, or DEBQ dimensions were observed across conditions (all $p > .05$). In contrast, significant main effects of gender and Condition × Gender interactions were observed across several food intake and hedonic response measures (Appendix A. *7*). Overall, female participants consumed significantly less pizza, fries, ice cream, and Greek yoghurt than male participants and reported significantly lower ratings of food pleasantness, overall liking, and enjoyment for most food items. Significant interaction effects further indicated that the magnitude of these gender differences varied across the environmental conditions for several food items, suggesting that gender moderated participants' behavioural and hedonic responses to the visual environments.

3.2. Electrophysiological Data

The multi-way ANOVA revealed significant effects of video condition on skin conductance (SC; $F(5, 359) = 9.24$, $p < .0001$), blood volume pulse (BVP) amplitude ($F(5, 359) = 6.54$, $p < .0001$), and heart rate (HR; $F(5, 359) = 3.58$, $p < .0001$). As shown in Figure 2, the *War Shelter* video elicited significantly higher SC and HR values and significantly lower BVP amplitude compared with the silent condition and the remaining video conditions (*Lake Cruise*, *Beach Scene*, *Pool Party*, and *Times Square Walkthrough*). These physiological responses were recorded during exposure to the video stimuli, before the eating task, and therefore reflect autonomic responses to the environmental conditions rather than to food consumption.

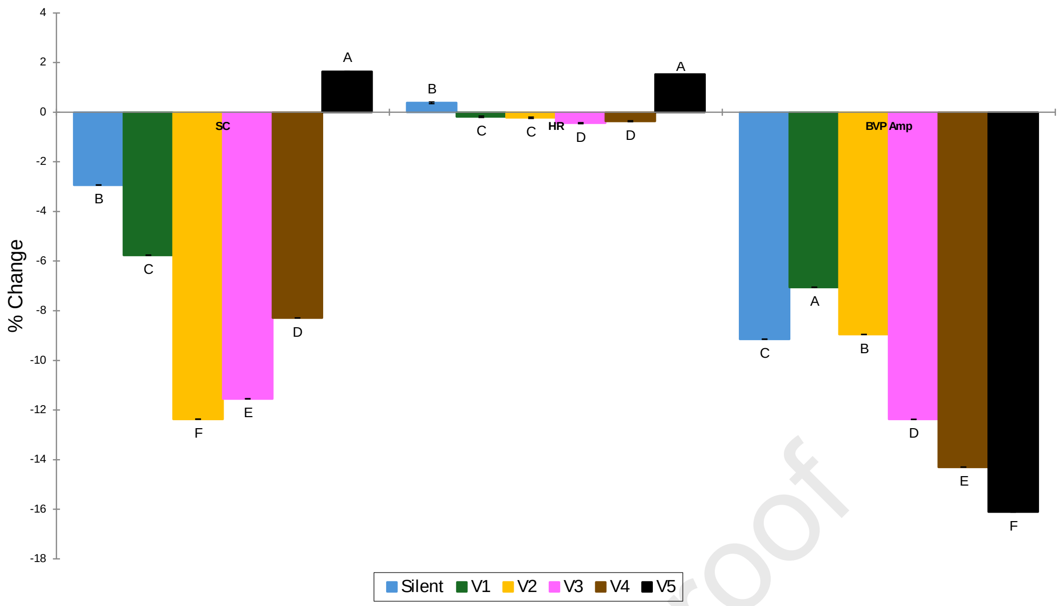


Figure 2. Percentage change values for skin conductance (SC), heart rate (HR) and blood volume pulse (BVP) amplitude. “Silent”, “Lake Cruise (V1)”, “Beach Scene (V2)”, “Pool Party(V3)”, “Times Square Walkthrough(V4)” Different lowercase letters (a–g) indicate significant differences in physiological measures across conditions.

3.3. Multiple Factor Analysis (MFA)

The MFA biplot, presented in Appendix A. 6, revealed a clear separation of eating environments along two primary dimensions. The first MFA dimension differentiated calm, low-arousal environments from stressful, high-arousal environments, with nature-based scenes (e.g., Beach Scene) associated with positive low-arousal emotions and higher blood volume pulse amplitude, and the War Shelter condition associated with negative high-arousal emotions alongside elevated heart rate and skin conductance. The second dimension differentiated low-engagement contexts (Silent, Lake Cruise) from stimulating environments (Pool Party, Times Square Walkthrough), which clustered with high-arousal positive emotions.

3.4. Emotion responses of participants after eating food items

Multidimensional alignment (MDA) was used to calculate cosine values between the six video conditions and self-reported emotions after participants consumed a lunch meal. Table 2 presents the emotions that were positively and negatively correlated with the different eating conditions using the first two dimensions of the bi-dimensional map produced by the CA. Cosine values greater than 0.707 (Carr et al., 2009) indicate a strong relationship between the video clip conditions and emotion attributes. With reference to Table 2, green values indicate a strong positive correlation (> 0.707) between emotion attributes and the eating conditions after consuming healthy and unhealthy food items under the “Silent” and other video environments. Orange values indicate a strong negative correlation (≤ 0.707) between emotion attributes and the eating conditions under the video environments “Lake Cruise”, “Beach Scene”, “Pool Party”, “Times Square Walkthrough” and “War Shelter”.

Table 2. Cosine values obtained from correspondence analysis representing the correlation between check-all-that-apply (CATA) emotion attributes and the six video conditions: “Silent”, “Lake Cruise”, “Beach Scene”, “Pool Party”, “Times Square Walkthrough”, and “War Shelter”, after participants consumed a lunch meal. Values highlighted in green and red indicate high positive and negative correlations, respectively.

	Condition					
	Silent	Lake Cruise	Beach Scene	Pool Party	Times Square Walkthrough	War Shelter
Active	-0.706	0.316	0.154	0.940	0.763	-0.537
Excited	0.131	0.852	0.918	0.390	-0.442	-0.866
Enthusiastic	-0.756	0.330	0.041	0.831	0.838	-0.414
Happy	-0.739	0.252	0.199	0.957	0.697	-0.504
At ease	-0.543	0.691	0.848	0.823	0.096	-0.776
Relaxed	0.304	0.714	0.897	0.286	-0.558	-0.823
Quiet	0.997	-0.130	-0.127	-0.697	-0.602	0.065
Bored	0.986	-0.133	-0.226	-0.750	-0.598	0.145
Uninspired	-0.034	-0.819	-0.760	-0.647	0.095	0.997
Unhappy	0.035	-0.840	-0.786	-0.685	0.090	0.995
Tense	0.351	-0.060	-0.457	-0.736	-0.482	0.588
Nervous	0.052	-0.804	-0.735	-0.708	-0.021	0.998

3.5. Effect of different environmental clips on healthy and unhealthy food intake

Multi-way ANOVAs examined the effect of video condition on food intake. As shown in Figure 3a the *Lake Cruise* condition was associated with significantly higher consumption of healthy foods, including mixed vegetables ($F(5,359) = 31.35$, $p < .001$, $\eta p^2 = 0.35$), Greek yoghurt ($F(5,359) = 25.12$, $p < .001$, $\eta p^2 = 0.29$), and cherry tomatoes ($F(5,359) = 21.65$, $p < .001$, ηp^2

= 0.27), compared with the *War Shelter*, *Times Square Walkthrough*, *Pool Party*, *Beach Scene*, and *Silent* conditions.

For unhealthy foods (Figure 3b), pizza intake was highest during the *War Shelter* condition ($F(5,359) = 141.54$, $p < .001$, $\eta p^2 = 0.70$). Fries ($F(5,359) = 23.48$, $p < .001$, $\eta p^2 = 0.28$) and ice-cream intake ($F(5,395) = 12.33$, $p < .001$, $\eta p^2 = 0.17$) were greatest during the *Pool Party* condition compared with all other video conditions.

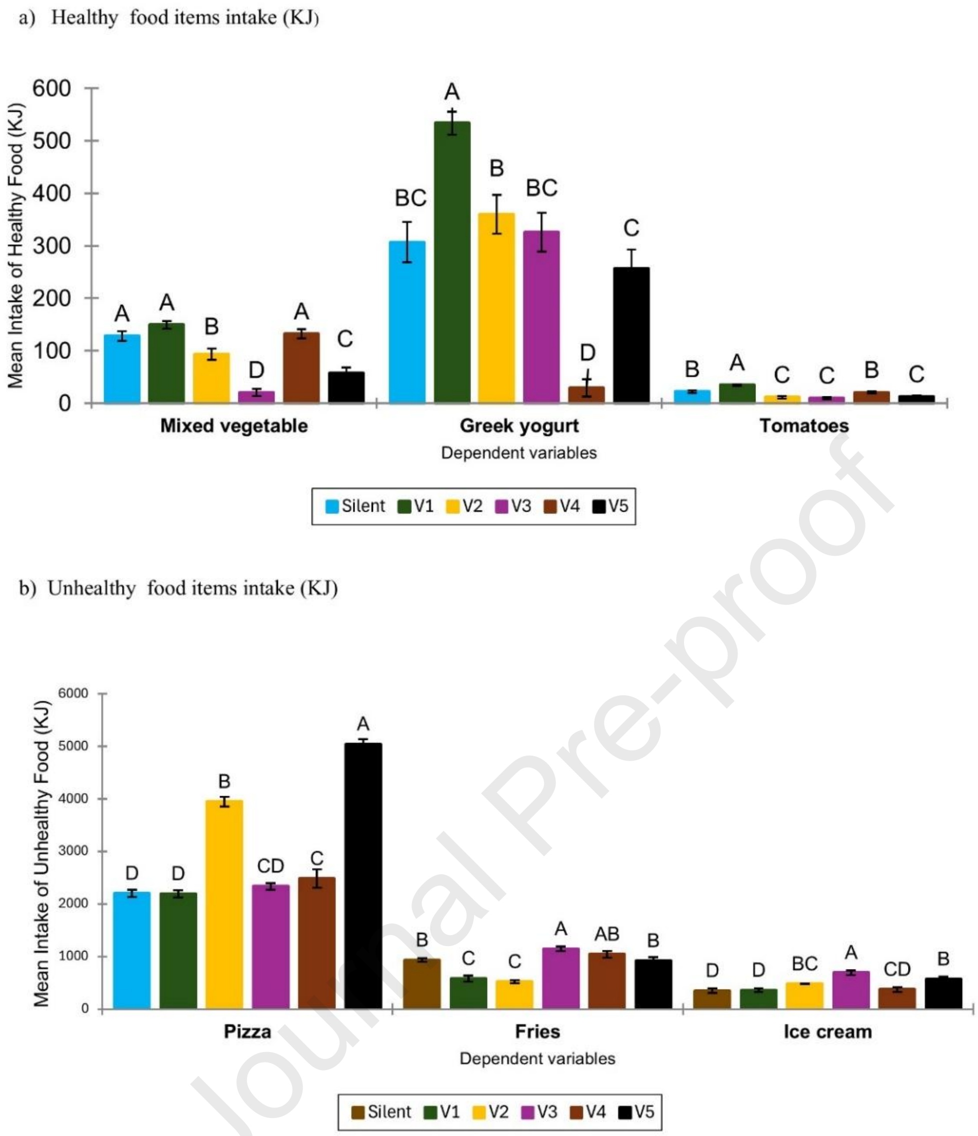


Figure 3. Food intake of healthy (Fig. 3a), and unhealthy (Fig. 3b) under the "Silent" condition and the five video environments: "Lake Cruise (V1)", "Beach Scene (V2)", "Pool Party(V3)", "Times Square Walkthrough(V4)" and "War Shelter(V5)". Results are expressed

as mean ± standard error (SE). Different superscripts ($^{A, B, C, D}$) indicate significant differences (p < .05). a)

3.7. The effect of video on rating of food items

The effects of environmental videos on hedonic measures were analyzed using multi-way ANOVA (Appendix A. *9*), revealing significant differences in ratings across the experimental conditions (Appendix A. *8*). Overall, healthy foods received higher pleasantness, liking, enjoyment, and satisfaction ratings under the low-arousal Lake Cruise condition, whereas unhealthy foods showed higher pleasantness ratings under the high-arousal Times Square Walkthrough condition. Perceived healthiness ratings were largely stable across video conditions, with healthy foods consistently rated as healthier than unhealthy foods. our study did not rely on theoretical assumptions alone; we empirically evaluated the construct validity of these scales using same-food correlation matrices. The analysis revealed extreme collinearity between Overall Liking and Enjoyment (r ranging from 0.89 to 0.98), confirming that the participants conflated them. Pleasantness exhibited a slightly more independent trajectory, capturing immediate sensory-specific appraisal, whereas Overall Liking and Enjoyment collapsed into a single unified construct. In response to this overlap and the reviewer's point, we have streamlined our reporting to focus on Overall Liking as the primary hedonic indicator, thereby eliminating redundancy and strengthening the methodological rigor of our findings (Jacquin-Piques, 2024)

Perceived healthiness ratings were largely stable across video conditions. Based on the rating scale (0 = Healthy, 10 = Unhealthy), healthy food items (mixed vegetables, Greek yoghurt, and tomatoes) consistently received lower scores than unhealthy food items (pizza, fries, and ice cream), indicating that participants accurately perceived the healthy foods as healthier than the unhealthy foods.

3.8.Appetite ratings

To evaluate the construct validity and independence of the subjective appetite measures, Pearson correlation matrices were computed for hunger, fullness, and satiation immediately before and after the meal (Table 3). Consistent with the literature (Gibbons, Hopkins, Beaulieu, Oustric, & Blundell, 2019), pre-consumption ratings demonstrated weak to moderate associations, indicating that these constructs capture distinct aspects of appetite regulation prior to eating. Conversely, post-consumption ratings exhibited extreme collinearity (e.g., fullness and satiation: $r = 0.862$), as the physiological event of food consumption forced the variables to align. A multi-way ANOVA analysed changes in hunger, fullness and satiation ratings before and after (VASpre − VASpost) the meal across all video conditions (*re*: Figure 4). Thus, larger positive hunger values indicate greater reductions in hunger following the meal, whereas negative fullness and satiation values indicate increases in fullness and satiation after eating. Hunger decreased significantly across all conditions, with the greatest reduction under "Times Square Walkthrough" ($F_{(5,395)} = 23.10$, $p < .0001$, $\eta p^2 = 0.17$), followed by "Lake Cruise" and "Beach Scene". The "Silent" condition also showed a significant decrease, while reductions were smallest under "War Shelter" and "Pool Party".

Fullness increased significantly in all conditions ($F(5,395) = 17.55$, $p < .0001$, $\eta p^2 = 0.21$), with the largest increase in "Times Square Walkthrough", followed by "Lake Cruise" and "Beach Scene". The smallest increase occurred under "War Shelter". Fullness ratings increased significantly in all conditions ($F_{(5,395)} = 17.55$, $p < .0001$, $\eta p^2 = 0.21$), with the largest increase in "Times Square Walkthrough", followed by "Lake Cruise" and "Beach Scene". The smallest increase occurred under "War Shelter" condition.

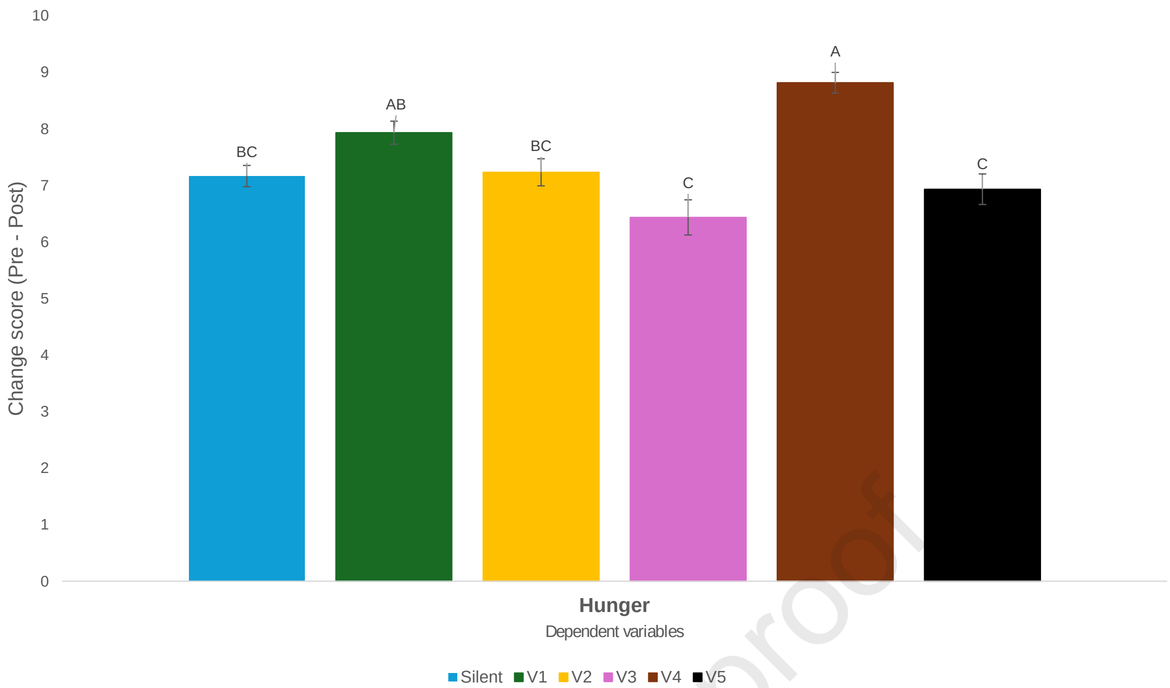
For satiated ratings ($F_{(5,395)} = 16.79$, $p < .0001$, $\eta p^2 = 0.46$), the most significant increase occurred under the "Silent" condition, followed by "Lake Cruise" and "Times Square Walkthrough". In contrast, changes were significantly smaller for "Beach Scene", "War Shelter" and "Pool Party".

Table 3. Pearson correlation coefficients (*r*) for subjective appetite ratings pre- and post-consumption.

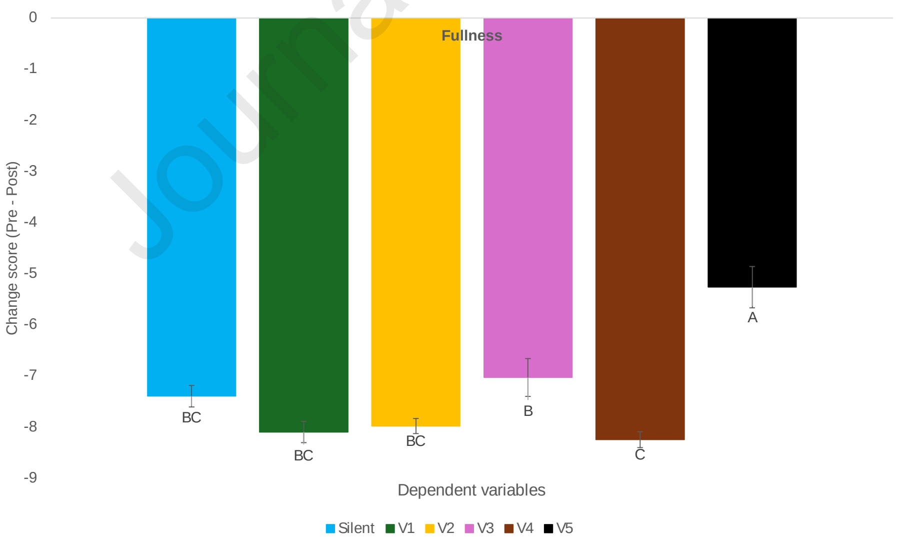
	Pre-consumption correlations			**Post-consumption Correlations**		
	Hunger	Fullness	Satiation	Hunger	Fullness	Satiation
Hunger	1	-0.253*	-0.056	1	-0.807***	-0.757***
Fullness	-0.253*	1	0.304**	-0.807***	1	0.862***
Satiation	-0.056	0.304**	1	-0.757***	0.862***	1

Note. N = 360. * $p < .05$, $p < .01$, *** $p < .001$.

a) Hunger



b) Fullness



c) Satiation

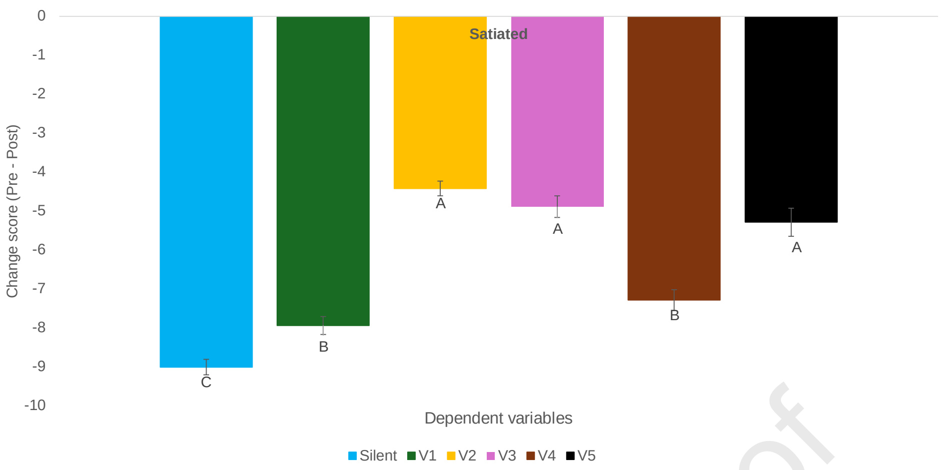


Figure 4. Mean changes in a) hunger, b) fullness, and c) satiated ratings after the lunch meal under six conditions: "Silent" (control), "Lake Cruise (V1)", "Beach Scene (V2)", "Pool Party (V3)", "Times Square Walkthrough (V4)" and "War Shelter (V5)". Results are expressed as mean VAS pre-meal minus post-meal ± standard error (SE). Different superscripts ($^{A, B,C,D,E}$) indicate significant differences at $p < .05$.

3.9. Integrated relationships among emotion, appetite, food liking, and intake during lunch consumption under different environment video conditions.

Appendix A. 10. presents a Multiple Factor Analysis (MFA) biplot integrating emotions, appetite ratings (hunger and fullness), food intake (healthy and unhealthy items), and hedonic evaluations across six video conditions. The first dimension (F1) explained 66.76% of the variance and the second dimension (F2) explained 30.53%. Lake Cruise (V1) was strongly correlated with healthy food intake, pleasantness, liking, enjoyment, satisfaction, relaxed emotions, and fullness, showing high positive loadings on F1. In contrast, pizza, fries, and ice-cream intake, high hedonic ratings for these foods, and high-arousal or negative emotions showed negative F1 loadings. Pool Party (V3) and Times Square Walkthrough (V4) were associated with higher indulgent intake and energetic or excited emotions, while War Shelter (V5) was linked to negative emotions and increased pizza intake. Silent was located near the origin, whereas Beach Scene (V2) loaded on F2 and was associated with calm emotions and modest healthy food responses.

3.10. Dynamic Bayesian Network (BN): the interact between physiological arousal, emotional states, liking, and dietary outcomes.

The network structure (Figure 5) learning algorithm converged after 44 iterations. The Bayesian Network illustrates the probabilistic relationships among physiological arousal, emotional states, food liking, and dietary outcomes. Arrows indicate conditional dependencies between variables rather than direct causal effects, while the strength of each connection is represented by the corresponding edge value. The final model demonstrated robust fit, with a Bayesian Information Criterion (BIC) score of -3139.49, representing a substantial improvement of 454.86 over the null model (-3594.36), confirming the validity of the hypothesised pathways.

Within the Bayesian Network, physiological arousal emerged as a key antecedent factor, meaning that it occupied an early position in the network and significantly influenced subsequent emotional states. High physiological arousal was positively associated with Excitement and Distress, while negatively associated with Contentment. Furthermore, physiological arousal showed a direct association with unhealthy food intake that was independent of hedonic liking. Conditional probability analysis indicated that under conditions of high physiological arousal, the probability of high unhealthy food intake increased to 52.7%.

Excitement, a high-arousal, positive valence emotional state within the circumplex model of affect, drove intake primarily through a hedonic route. Excitement was strongly associated with increased Unhealthy Food Liking, which in turn was the strongest proximal predictor of Unhealthy Food Intake. Posterior probability analysis indicated that when participants were in a state of high excitement, the probability of engaging in high levels of unhealthy intake was 52.7%. In contrast, contentment, representing a low-arousal positive emotional state, facilitated a health-oriented pathway. Contentment was positively associated with Healthy Food Liking, which subsequently showed a robust association with Healthy Food Intake. These probabilities indicate that calm, positive environments align hedonic preference with healthier dietary choices.

A distinct non-hedonic pathway was observed for distress, a high-arousal negative emotional state. Distress showed a direct positive association with Unhealthy Food Intake that bypassed the Unhealthy Food Liking node. Conditional probability analysis revealed that the presence of Distress increased the probability of high unhealthy food intake to 73 %. This direct pathway suggests that unhealthy food intake under distress was not primarily mediated by hedonic liking and is consistent with a stress-related eating mechanism in which emotional distress may contribute directly to unhealthy food consumption. Finally, low-arousal negative affect (Boredom) showed only a weak association with satiation and a minor link to intake, suggesting that boredom played a less central role in driving specific food choices within this experimental context compared to arousal-driven states.

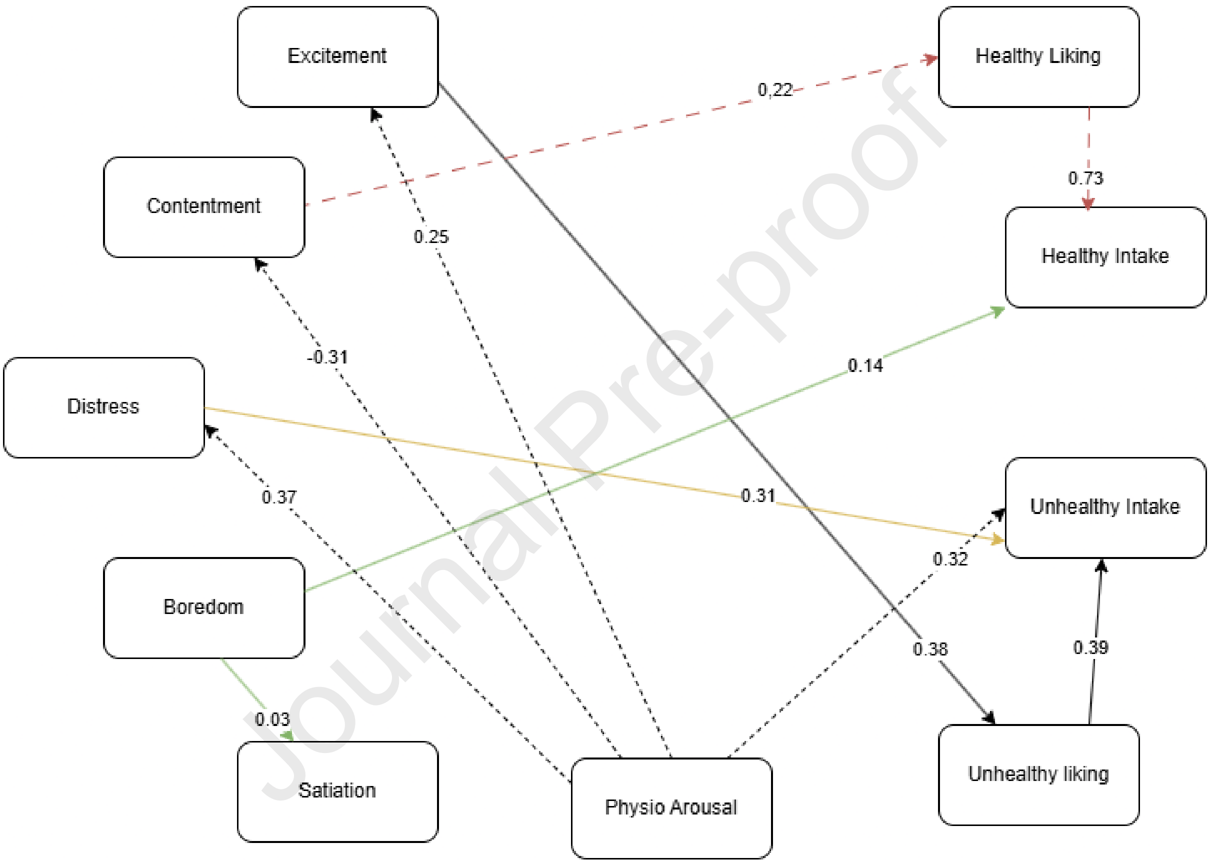


Figure 5. Bayesian Network (BN) model mapping the Stimulus-Organism-Response (S–O–R) pathways for food intake. Black dashed arrows indicate that physiological arousal was modelled as an antecedent variable in the Bayesian Network, directly influencing subsequent emotional states (Excitement, Distress, and Contentment). Red dashed arrows represent liking-mediated healthy pathways, whereby low-arousal positive emotions condition Healthy Liking, which strongly predicts Healthy Intake (0.73). Green solid arrows indicate health-supportive or regulatory pathways associated with low-engagement states, showing modest contributions of Boredom to Healthy Intake (0.14) and Satiation (0.03). Yellow solid arrows reflect stress-related emotional influences, with Distress directly predicting Unhealthy Intake (0.31), independent of hedonic liking. Edge values represent path strengths.

4. Discussion

This study examined how video-based visual-affective cues differing in valence, arousal, and motion influenced hedonic evaluation, food intake, and emotional responses during meal consumption. By integrating subjective emotional responses, electrophysiological indices of autonomic arousal, and Bayesian Network modelling, the study extends prior work that has often focused on isolated emotional effects or static imagery. Specifically, it investigated whether calm, low-arousal visual contexts were associated with more health-oriented eating patterns, whereas highly arousing positive or negative visual contexts were associated with increased indulgent intake through both liking-mediated and affect-regulatory pathways. Although these cues were presented as video stimuli rather than as real dining environments, the findings provide a basis for considering how affective qualities of eating contexts may shape consumer responses in hospitality settings.

4.1. Environmental Affective Cues Drive Eating Behaviour

Eating behaviour in gastronomy is shaped by the affective properties of the surrounding environment, with contextual cues often guiding consumption more strongly than food attributes alone (Wansink & van Ittersum, 2012; Mathiesen, Mielby, Byrne, & Wang, 2020). Low-arousal or socially salient contexts can enhance self-monitoring during eating, reducing the acceptability of indulgent foods while increasing preference for healthier options (King, Weber, Meiselman, & Lv, 2004). Consistent with this mechanism, calm visual contexts in the present study were associated with healthier intake, whereas more stimulating or stressful video contexts were associated with greater energy-dense food consumption.

Calm, low-arousal scenes (e.g., Lake Cruise) elicited positive emotions such as relaxation and contentment and were associated with higher intake of vegetables, yoghurt, and tomatoes. In contrast, high-arousal video contexts (e.g., Pool Party, Times Square Walkthrough, War Shelter) were associated with increased consumption of indulgent foods. This pattern was consistent across behavioural and multivariate analyses, indicating that environmental cues influence eating beyond subjective liking alone. These findings align more broadly with evidence that calm and less stimulating eating contexts can support health-oriented decision-making by reducing cognitive and affective load (Langlois & Chandon, 2024). Related work in both physical and digital settings suggests that affective qualities of the surrounding context, including calmness, visual simplicity, and lower stimulation, can influence emotional responses, stress, and food-related decision-making (Van Oudenhove, et al., 2011). Comparable effects have also been observed in digital contexts, where calm nature imagery increases preference for low-calorie foods compared with visually complex urban scenes (Liem, Mawas, & Keast, 2023). Although the present study did not manipulate "nature" as a specific experimental factor, the results suggest that calmer visual contexts may be associated with healthier food choices and more positive eating experiences.

4.2. Valence and Arousal Shape Hedonic Appraisal and Intake

The current findings are best interpreted within a circumplex-inspired framework that conceptualises affect along orthogonal dimensions of valence and arousal (James A. Russell; Jaeger et al., 2020). Within this framework, the present results demonstrate that arousal, rather than emotional valence alone, may be an important regulatory mechanism associated with eating behaviour, consistent with affect-regulatory models of food intake (Macht, 2008). Feeling "good" does not uniformly promote healthier choices, instead, the intensity of emotional activation determines whether affective states support reflective self-regulation or biases consumption toward immediate reward, as observed in the differential intake patterns across low- and high-arousal video conditions in the current study.

Low-arousal positive states preserve cognitive control and enhance interoceptive awareness, increasing sensitivity to internal satiety cues rather than external food signals (Blass, et al., 2006).

In contrast, high-arousal states, regardless of valence, shift eating behaviour away from homeostatic regulation toward affect-driven consumption. Heightened arousal weakens self-regulatory capacity and promotes intake of energy-dense foods even in the absence of hunger (Van Oudenhove et al., 2011). This mechanism explains why arousal-rich contexts often promote intake of energy-dense foods even in the absence of hunger and despite stable or declining hedonic enjoyment.

Experimental evidence further shows that arousal, rather than positive mood alone, determines whether individuals prioritise long-term health goals or immediate gratification (Fedorikhin & Patrick, 2010) . While low-arousal positive states support deliberative, future-oriented choices, high-arousal states favour indulgent behaviour by depleting cognitive resources required for self-control.

4.3. Dual Affective Pathways to Eating

Multiple Factor Analysis (MFA) and Bayesian Network (BN) modelling provide converging evidence for two affective pathways linking video-based visual-affective context to eating behaviour. MFA showed that low-arousal positive environments (e.g., Lake Cruise, Beach Scene) clustered with calm emotional states, healthier intake, favourable hedonic evaluations, and greater fullness. In contrast, high-arousal video contexts clustered with increased intake of energy-dense foods regardless of valence, highlighting physiological arousal as an important mechanism associated with disrupted homeostatic regulation. Extending these findings, BN analysis identified physiological arousal as a key antecedent factor that probabilistically influenced emotional states and, in turn, intake behaviour.

Elevated arousal increased the probability of excitement and distress while reducing contentment and biasing intake toward unhealthy foods. Within this structure, excitement influenced intake through a liking-mediated hedonic pathway, with unhealthy food liking emerging as the strongest proximal predictor. This suggests that high-arousal positive states enhance the motivational salience of energy-dense foods, consistent with distinctions between "wanting" and "liking" (Berridge & Kringelbach, 2015).

A distinct pathway was observed for distress. BN results showed that distress was directly associated with unhealthy intake independent of liking, indicating an affect-regulatory mechanism. This extends MFA findings by demonstrating that negative high-arousal states shift consumption toward regulation of aversive internal states rather than culinary appreciation, consistent with emotional-eating frameworks (Macht, 2008; Van Oudenhove et al., 2011).

Physiological responses supported this interpretation. The War Shelter condition elicited elevated heart rate and skin conductance alongside reduced blood volume pulse amplitude, reflecting heightened sympathetic activation (Zhai & Barreto, 2008; Roe & Aspinall, 2011). Such activation is associated with reduced sensitivity to internal satiety cues and increased reliance on externally driven eating. Importantly, these physiological responses were recorded during exposure to the environmental video stimuli, before participants began eating. Therefore, they represent autonomic responses to the viewing environment rather than physiological responses to food consumption itself, providing an indication of the physiological state that preceded, and may have influenced subsequent food intake and hedonic evaluations.

In addition to physiological responses, cognitive mechanisms may also help explain the observed eating behaviour. High-arousal video stimuli are likely to capture attentional resources and increase cognitive load, thereby reducing individuals' ability to monitor internal appetite-related signals while eating. This attentional diversion may impair awareness of hunger, fullness, and satiation, leading individuals to rely more heavily on external environmental cues and the rewarding properties of food. Previous studies have shown that distraction during eating can increase energy intake and weaken self-regulatory processes by reducing attention to internal appetite cues (Blass et al., 2006; Ogden et al., 2013; McCrickerd & Forde, 2016). Consequently, the greater unhealthy food intake observed under high-arousal conditions may reflect the combined effects of heightened physiological arousal and increased cognitive distraction.

Whereas prior work has linked autonomic responses during video exposure primarily to changes in flavour perception (Xu et al., 2019; Lin et al., 2025), the present findings suggest that physiological arousal may also be associated with intake behaviour. Under high-arousal conditions, cognitive and physiological resources are diverted toward managing environmental demands, weakening self-regulation and attenuating satiety signalling. Consequently, under high-arousal conditions, consumption may shift from hedonic enjoyment toward affect regulation, consistent with psychobiological models of stress-related eating (Adam & Epel, 2007; Sominsky & Spencer, 2014).

Although the present findings highlight physiological arousal as an important mechanism associated with eating behaviour, food choice is widely recognised as a multifactorial process influenced by physiological, cognitive, emotional, environmental, and social factors (Macht, 2008; Biswas et al., 2017; Van Oudenhove et al., 2011). Therefore, physiological arousal should be considered one component of a broader network of mechanisms underlying eating behaviour.

In addition to these factors, the present findings indicate that gender may also influence the relationship between affective environmental cues and eating behaviour. Significant Condition × Gender interactions were observed across several food intake and hedonic evaluation measures, suggesting that males and females responded differently to specific emotional environments. These findings are consistent with previous research demonstrating that gender differences in food preferences and hedonic responses are influenced by both sensory perception and psychological characteristics (Spinelli et al., 2025). Although the present study did not assess taste responsiveness or anxiety-related personality traits, the observed gender-specific responses suggest that emotional processing may interact with individual characteristics to shape eating behaviour. Future research should investigate how emotional states and gender jointly influence food choice and intake across different environmental contexts.

4.4. Implications for Designing Eating Environments

Findings from this study suggest that visual-affective cues may be a modifiable influence on eating behaviour that operates beyond individual food preferences. Although the present study did not directly manipulate real dining environments, the findings suggest that calm, low-arousal visual contexts may support healthier food choices by reducing physiological arousal and cognitive load. In the present study, low-arousal, positive visual contexts characterised by calmness and comfort were associated with healthier food choices and greater satiety-related responses, suggesting that such contexts may support more reflective food-related decision-making and consumption of nutrient-rich foods. For chefs, restaurateurs, and hospitality designers, these findings may have implications for the design of eating environments. More broadly, design features that create calmer and less stimulating eating contexts, such as coherent spatial layouts, soft lighting, subdued soundscapes, or visually soothing imagery, may support a more reflective and internally regulated eating experience. However, whether this is desirable is likely to depend on the goals of the dining occasion and the type of hospitality setting. In some contexts, such as health-oriented dining spaces, workplace cafeterias, or settings where supporting satiety and healthier food choices is a priority, calmer environments may be beneficial. In contrast, in celebratory, social, or indulgence-oriented dining settings, consumers may prefer more stimulating and energetic atmospheres that enhance excitement, sociability, and sensory engagement. Accordingly, the present findings should not be interpreted as suggesting that low-arousal environments are universally preferable, but rather that different affective contexts may support different dining goals. Although multisensory eating environments may not consistently reduce immediate intake, they may improve emotional wellbeing and support conditions conducive to healthier decision-making (Hoppu, Puputti, Mattila, Puurtinen, & Sandell, 2020).

Conversely, the present findings suggest that highly arousing visual contexts, whether exciting or stressful, may amplify reward sensitivity and weaken self-regulatory control, thereby promoting greater consumption of energy-dense foods (Evers, Adriaanse, de Ridder, & de Witt Huberts, 2013; Privitera, Diaz, & Haas, 2014). Stressful contexts may further increase reliance on energy-dense 'comfort foods' to dampen physiological strain associated with hypothalamic–pituitary–adrenal axis activation (Dallman, et al., 2003; Tomiyama, Dallman, & Epel, 2011).

Accordingly, if these effects generalise to real hospitality settings, reducing excessive noise, visual clutter, and time pressure may help limit cognitive load and physiological stress. Where stimulation is desirable, strategies such as portion control and balanced menu design may help mitigate indulgent intake.

These findings also highlight the potential importance of cognitive load in eating-context design. Visually complex and dynamic stimuli, such as highly stimulating urban scenes, may overload attentional resources, distort portion perception, and promote mechanical eating by diverting attention from internal satiety cues (Blass, et al., 2006; Ogden, et al., 2013). Such conditions impair accurate estimation of food quantity and weaken satiety–intake coupling (McCrickerd & Forde, 2016), highlighting the importance of simplicity in both physical and digital food environments.

The physiological findings further suggest that heightened autonomic arousal may reduce sensitivity to internal appetite cues, including hunger, fullness, and satiation, thereby impairing self-regulation. In digital food environments, low-arousal interface designs, including simplified layouts, muted colours, and minimal dynamic elements, may reduce cognitive load and support more mindful eating. Incorporating portion guidance and visual satiety cues may provide scalable strategies to reduce mindless overeating and support healthier consumer choices (Petit, Velasco, & Spence, 2019).

Although the present study used video-based environmental cues rather than real dining spaces, the findings provide a basis for considering how affective qualities of eating contexts may shape food choice and sensory enjoyment in hospitality settings. Virtual reality (VR) offers greater immersion and presence than conventional video-based stimuli and therefore has the potential to enhance ecological validity (Long et al., 2023; Curi Braga et al., 2025). Future research should investigate whether the relationships observed in the present study are replicated or strengthened in fully immersive VR dining environments.

A limitation of the stimulus set is that the source clips differed in native duration and shorter clips were repeated to maintain continuous presentation during the session. Although this approach standardised overall exposure to the assigned video context, repeated viewing of shorter clips may have influenced familiarity, attentional engagement, or emotional habituation differently across conditions. In addition, because motion was not manipulated as an independent orthogonal factor, the present study cannot isolate the specific contribution of visual movement from the broader affective and contextual properties of the clips.

A limitation of the present study is that eating rate and the order of food selection were not recorded. Previous research has shown that eating rate influences energy intake and differs according to food texture and energy density (Forde & Bolhuis, 2022). Future studies should incorporate behavioural measures such as eating sequence and eating rate to better understand the mechanisms underlying environmentally driven changes in food intake.

5. Conclusion

This study demonstrates that visual-affective environments are systematically associated with consumer food choices and sensory enjoyment through integrated physiological and emotional processes. By combining behavioural, physiological, and probabilistic modelling approaches, the findings provide a comprehensive account of how the multisensory dining context relates to food intake and hedonic appraisal.

Physiological arousal emerged as a key antecedent factor associated with dietary outcomes, linking environmental stimuli to consumption through two distinct pathways: a liking-mediated pathway associated with excitement and a direct, affect-regulatory pathway associated with distress. These results suggest that eating behaviour is shaped not only by intrinsic food properties but also by the affective characteristics of the surrounding dining space.

Importantly, low-arousal environments were consistently associated with increased intake and sensory liking of nutrient-dense foods and improved satiety responses, whereas high-arousal environments were associated with greater consumption of energy-dense foods. This highlights the role of arousal in shaping non-homeostatic eating patterns.

These findings have practical implications for the design of contemporary dining environments, particularly in digitally mediated or multisensory dining contexts where visual stimuli are pervasive. Designing low-arousal, cognitively accessible environments may support mindful eating and health-oriented culinary experiences. Future research should extend these findings to real-world restaurant settings to further evaluate the role of hospitality design in promoting mindful, enjoyable, and sustainable gastronomic experiences.

Author Contributions

Phatharachanok Siangphloen: Writing – review & editing, Writing– original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. Daniel Shepherd: Writing – review & editing, Writing – original draft, Supervision, Software, Resources, Project administration, Funding acquisition, Conceptualization. Kevin Kantono: Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Methodology, Formal analysis, Data curation. Nazimah Hamid: Writing – review & editing, Writing – original draft, Supervision, Project administration, Funding acquisition, Data curation, Conceptualization.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data will be made available on request.

Appendices

Appendix A.1. Participant characteristics expressed as mean ± SE, and range (min and max) in parentheses.

	Experimental Condition					
	Silent	**V1**	**V2**	**V3**	**V4**	**V5**
N	60	60	60	60	60	60
(M/F)	(28/32)	(30/30)	(31/29)	(30/30)	(32/28)	(34/26)

Age (years)	25.93 ± 0.83 (18-50)	25.97 ± 0.81 (18-50)	25.3 ± 0.68 (18-44)	26.07 ± 0.7 (18-44)	26.37 ± 0.70 (18-38)	26.67 ± 0.78 (18-43)
Waist (cm)	33.33 ± 0.80 (26-47)	34.40 ± 1.69 (23.6-96.5)	32.83 ± 0.67 (23-46)	31.03 ± 0.53 (36-25)	29.88 ± 0.52 (32-28)	31.18 ± 0.76 (42-23.6)
BMI (kg/m^2)	24.61 ± 0.68 (16.98-41.62)	23.81 ± 0.63 (17.58-45.04)	23.92 ± 0.50 (39.18-17.32)	22.09 ± 0.66 (40.18-16.67	23.88 ± 0.50 (38.58-17.48)	23.60 ± 0.5 (38.47-0.5)
DEBQ-restraint eating	3.27 ± 0.11 (1.3-5)	2.69 ± 0.09 (3.8-1)	2.86 ± 0.09 (4.4-1.3)	2.98 ± 0.19 (4.6-1)	3.20 ± 0.12 (5-1.2)	3.28 ± 0.12 (5-1.1)
DEBQ-emotional eating	3.31 ± 0.13 (1.08-4.92)	2.79 ± 0.11 (4.38-1)	2.60 ± 0.11 (4.77-1)	2.92 ± 0.13 (4.69-1)	3.41 ± 0.12 (4.85-1)	3.09 ± 0.13 (4.62-1.15)
DEBQ-external eating	2.78 ± 0.10 (1.4-4.4)	2.93 ± 0.09 (4.2-1.9)	3.11 ± 0.09 (4.5-2)	2.90 ± 0.10 (4.5-1.6)	2.64 ± 0.10 (4.1-1.3)	2.48 ± 0.10 (4.1-1)

DEBQ Dutch Eating Behaviour Questionnaire

Appendix A. 2. Lunch items used in the study.

Twenty participants rated the perceived healthiness of lunch items in silence or while viewing four different environmental clips (Appendix A. 4). Based on the mean healthiness ratings, three food items were selected to represent healthy foods and three unhealthy foods, resulting in six foods used in the main experiment (*re*:Appendix A. 3). The portion sizes of each food item were in accordance with the manufacturer's recommended serving sizes, with an approximate total energy value of 5425.5 KJ. Unhealthy options included a cheese pizza and French fries (Pizza Hut, Auckland, New Zealand), and ice cream (Magnum Mini Classic, Unilever). Healthy alternatives comprised mixed vegetables consisting of broccoli, carrot, and cauliflower (Birds Eye Steamfresh;), cherry tomatoes), and Greek yoghurt (Yoplait Greek Natural Yoghurt). Food intake was quantified by weighing each food item before and after consumption. The difference in weight was used to calculate intake for healthy and unhealthy foods separately, and values were subsequently converted to energy intake (kJ) based on nutritional information obtained from manufacturer data and the New Zealand Food Composition Database. Detailed descriptions of food types, brands, portion sizes, and energy Density (kcal/g) in table. Energy calculations were based on nutritional information obtained from the Pizza Hut New Zealand website (www.pizzahut.co.nz), Streets Ice Cream (www.streetsicecream.co.nz), and Birds Eye Mixed Vegetables - Carrot, Cauliflower & Broccoli

(https://birdseye.co.nz/product/birds-eye-steamfresh-carrot-cauliflower-and-broccoli-3-packs/43132), as well as the New Zealand Food Composition Database (New Zealand Institute of Plant and Food Research, 2021; www.foodcomposition.co.nz/downloads/concise-14-edition.pdf).

Lunch items used in the study.

Food Item	**Weight (g)**	**Calories (kcal)**	**Calculation (kcal / g)**	**Energy Density**
Cherry tomatoes (Woolworths Fresh Tomatoes Strawberry	50	9.0	9.0 / 50	**0.18 (Low)**
Mixed vegetables with broccoli, carrot, cauliflower (Birds Eye Steamfresh,	150	44.0	44.0 / 150	**0.29 (Low)**
Geek yoghurt (Yoplait Yoghurt Greek Natural	125	123.5	123.5 / 125	**0.99 (Low)**
Fries (Pizza Hut, Auckland, NZ)	124	289.0	289.0 / 124	**2.33 (Medium)**
Cheese pizza (Pizza Hut, Auckland, NZ)	280	663.9	663.9 / 280	**2.37 (Medium)**
Ice cream (Magnum mini classic, Auckland, NZ)	49	167.3	167.3 / 49	**3.41 (Medium)**

Appendix A. 3. Affective and dynamic characteristics of the five environmental video stimuli (V1–V5).

A preliminary study was conducted to select appropriate environmental video stimuli for the main experiment. This screening involved 200 participants (102 males and 98 females) aged between 20 and 60 years (M_{age} = 26.8 years, SD = 7.4) who completed an online survey hosted on Qualtrics. The survey featured 26 one-minute video clips representing diverse environments . To ensure experimental consistency, the video clips were edited using Adobe Premiere Pro 2023 and audio levels standardised in Adobe Audition 2023 to equalise root mean square (RMS) amplitude.

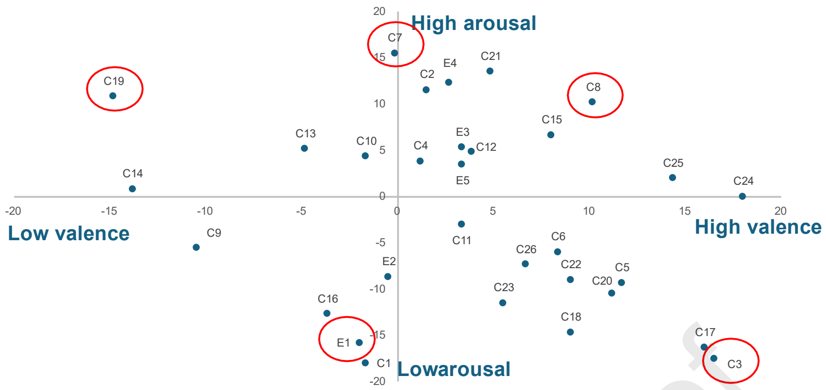
Video Label	Title/Link	Type of video clips and duration	Description
V1	 https://www.youtube.com/watch?v=jIosRoU1UeI	Moving clips (14.28 mins)	**Queenstown Lake Cruise**: Calm, scenic views of Lake Wakatipu and surrounding mountains. Peaceful catamaran ride. Promotes relaxation and tranquility.
V2	 https://www.youtube.com/watch?v=ZDZ4oF4VrHI&t=344s	Stationary (08.07 mins)	**Beach Scene**: Soft ocean waves, white sand, blue sea, and palm trees. A gentle, soothing tropical vibe.
V3	 https://www.youtube.com/watch?v=DXOUctXOJz4	Stationary (2.24 mins)	**Las Vegas Pool Party**: Energetic party scene with DJ, dancing crowd, and luxurious pool atmosphere. Bright and upbeat.
V4	 https://www.youtube.com/watch?v=mNnTt5NVDC4	Moving Clip (11.28 mins)	**Times Square Walkthrough**: Crowded streets, street performers, LED billboards, and bright city lights. Busy and stimulating.
V5	 https://www.youtube.com/watch?v=L76e6vVJbI0&t=20s	Stationary (2.00 mins)	**WWII Anderson Shelter**: War-time soundscape with air raid sirens, bombing noises, and creaking shelter sounds. Tense and unsettling.

Appendix A. 4. Ranking of Pilot Tested Food and snack items to be used in this study. Rating was measured using 10 -point hedonic scale ranging from 1 “healthy” to 10“unhealthy

	Silent	High valence-Low Arousal	Low Valence - High Arousal	High Arousal	Low Arousal	F(df)	*p*
Donut	7.987	8.831	8.381	8.531	7.981	F(4,24) =0.832	0.686
Cheese pizza	7.574	7.755	7.905	7.455	7.405	F(4,24) =1.126	0.339
Milk tea	7.337	7.476	6.476	6.526	5.926	F(4,24) = 1.375	0.151
Ice cream	8.180	8.193	8.143	7.793	6.593	F(4,24) = 1.118	0.347
Fried	8.399	7.983	7.333	8.183	6.983	F(4,24) = 1.092	0.374
Trim milk	1.625	1.750	2.000	1.700	2.550	F(4,24) = 1.292	0.20
Cherry tomatoes	2.165	1.126	1.476	1.076	1.926	F(4,24) = 0.66	0.873
Greek yoghurt	2.256	1.824	1.524	1.124	2.274	F(4,24) = 1.039	0.432
Summer rolls	1.447	1.245	2.095	1.795	2.595	F(4,24) = 1.185	0.284
Mixed vegetable	3.560	2.493	2.143	2.693	2.243	F(4,24) = 1.252	0.229

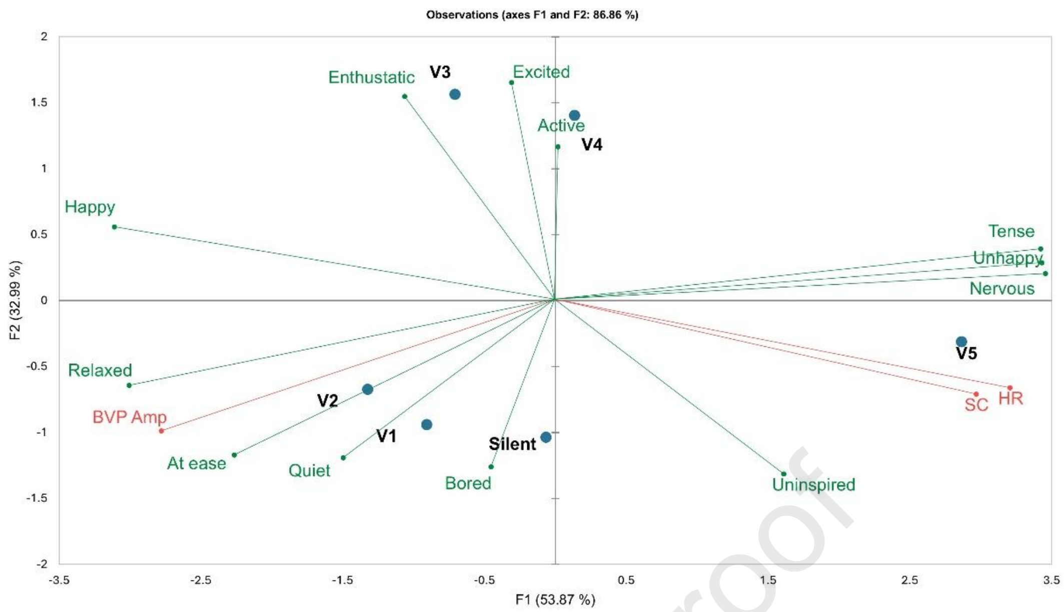
Pre-Test correspondence analysis (CA) (video selection) (Appendix A.5)

The CATA method required participants to identify applicable emotions by selecting the relevant terms from this list. To ensure the reliability of the data and reduce potential order effects, the sequence of the CATA terms presented to participants was counterbalanced across and within individuals, utilising a Williams Latin square design. All responses related to emotional states were collected via the online Qualtrics platform.



Appendix A. 6. Multiple Factor Analysis (MFA) biplot of emotions and physiological responses across environmental conditions

The first dimension (F1) and second dimension (F2) explained 53.87% and 32.99% of the variance in the data, respectively. Viewing the “Beach Scene” resulted in high negative scores along F1, which were associated with positive emotions such as happy and relaxed, as well as with BVP amplitude. Viewing the “War Shelter” produced high positive scores along F1 and was associated with emotions including uninspired, tense, nervous and unhappy, together with higher HR and SC. Factor 2 (F2) accounted for 30.53% of the variability and was linked to the “Lake Cruise”, “Pool Party” and “Times Square Walkthrough” conditions. The “Lake Cruise” showed high negative scores along F2, correlating with the emotion at ease. The “Silent” condition was associated with emotions such as quiet, bored and uninspired. Conversely, viewing the “Pool Party” and “Times Square Walkthrough” resulted in high positive scores along F2, which correlated with positive emotions that included active, excited and enthusiastic.



Multiple Factor Analysis (MFA) biplot of Factor 1 and Factor 2 showing twelve emotion descriptors (green) and physiological measures (red) for six environmental video conditions: "Silent", "Lake Cruise" (V1), "Beach Scene" (V2), "Pool Party" (V3), "Times Square Walkthrough" (V4) and "War Shelter" (V5).

Appendix A. 7. Gender differences in food intake, pleasantness, liking, and enjoyment

gender effects were observed across food intake and hedonic responses. Female participants consumed significantly less pizza, fries, ice cream, and Greek yoghurt than male participants. Females also reported significantly lower ratings of food pleasantness, overall liking, and enjoyment across most food items, including both healthy and unhealthy options. Differences for mixed vegetables were comparatively small.

Food Item	Measure	Male (M ± SE)	Female (M ± SE)	F-value	Gender *p-value*	Condition × Gender *p-value*
Pizza	Intake (g)	3480.08±39.42	2581.26±40.54	26.07	***	***
	Pleasantness	8.11±0.12	6.63±0.12	7.63	***	***
	Liking	7.75±0.10	6.13±0.10	12.53	***	***
	Enjoyment	7.56 ± 0.10	5.90 ± 0.11	11.12	***	***

Fries	Intake (g)	1017.09±25.35	689.81±26.07	10.62	***	***
	Pleasantness	7.30±0.18	4.98±0.19	6.99	***	***
	Liking	6.83±0.16	4.70±0.16	11.30	***	***
	Enjoyment	6.78±0.16	4.65±0.16	13.22	***	***
Ice cream	Intake (g)	599.42±20.86	380.96±21.45	4.96	***	***
	Pleasantness	7.15±0.27	4.81±0.28	5.49	***	***
	Liking	6.84±0.25	4.67±0.26	5.24	***	***
	Enjoyment	6.77±0.24	4.58±0.25	5.72	***	***
Greek yoghurt	Intake (g)	96.48 ±16.89	93.46±17.37	9.13	***	***
	Pleasantness	5.14±0.24	3.68±0.25	6.09	***	***
	Liking	4.67±0.23	3.24±0.24	4.16	**	***
	Enjoyment	4.65±0.23	3.16±0.24	4.51	***	***
Mixed vegetables	Intake (g)	360.96±4.95	233.96±5.06	18.87	***	**
	Pleasantness	4.66±0.23	4.65±0.23	5.04	***	***
	Liking	4.30±0.22	4.22±0.23	3.52	**	**
	Enjoyment	4.34±0.22	4.34±0.22	3.51	**	**

Note. Error bars represent standard errors. ** p < .05, ** p < .01, *** p < .001 (significant gender effects).* Condition × Gender interaction obtained from the two-way ANOVA, indicating whether the effect of the environmental condition differed between males and females.

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806 Appendix A. 8. Multi-way ANOVA results for the effects of audiovisual environment on food
807 liking, pleasantness, and satisfaction

Food category	Food item	Dependent variable	Environment with highest rating	F(df)	p-value	Partial η²
Healthy	Mixed vegetables	Overall pleasantness	Lake Cruise (V1)	F(46,134) = 2.52	< .0001	0.70
		Flavour pleasantness	Lake Cruise (V1)	F(46,134) = 2.44	< .0001	0.41
		Enjoyment	Lake Cruise (V1)	F(46,134) = 4.53	< .0001	0.41
		Satisfaction	Lake Cruise (V1)	F(46,134) = 3.60	< .0001	0.35
		Overall liking	Lake Cruise (V1)	F(46,134) = 3.91	< .0001	0.38
Healthy	Greek yoghurt	Overall pleasantness	Lake Cruise (V1)	F(46,134) = 2.52	< .0001	0.70
		Flavour pleasantness	Lake Cruise (V1)	F(46,134) = 2.44	< .0001	0.41
		Enjoyment	Lake Cruise (V1)	F(46,134) = 4.53	< .0001	0.41
		Satisfaction	Lake Cruise (V1)	F(46,134) = 3.60	< .0001	0.35
		Overall liking	Lake Cruise (V1)	F(46,134) = 3.91	< .0001	0.38
		Perceived healthiness	Silent	F(46,134) = 13.47	< .0001	0.80
Healthy	Tomatoes	Overall pleasantness	Lake Cruise (V1)	F(64,359) = 3.38	< .0001	0.35
		Perceived healthiness	Silent	F(64,359) = 8.46	< .0001	0.90
Unhealthy	Pizza	Overall pleasantness	Times Square Walkthrough (V4)	F(64,359) = 2.69	< .0001	0.37
		Perceived healthiness	Pool Party (V3)	F(64,359) = 4.23	< .0001	0.87
Unhealthy	Fries	Overall pleasantness	Pool Party (V3)	F(64,359) = 3.32	< .0001	0.42
		Perceived healthiness	Pool Party (V3)	F(64,359) = 2.31	0.043	0.92
Unhealthy	Ice cream	Overall pleasantness	Pool Party (V3)	F(64,359) = 2.18	< .0001	0.32
		Perceived healthiness	Pool Party (V3)	F(64,359) = 4.65	.000	0.89

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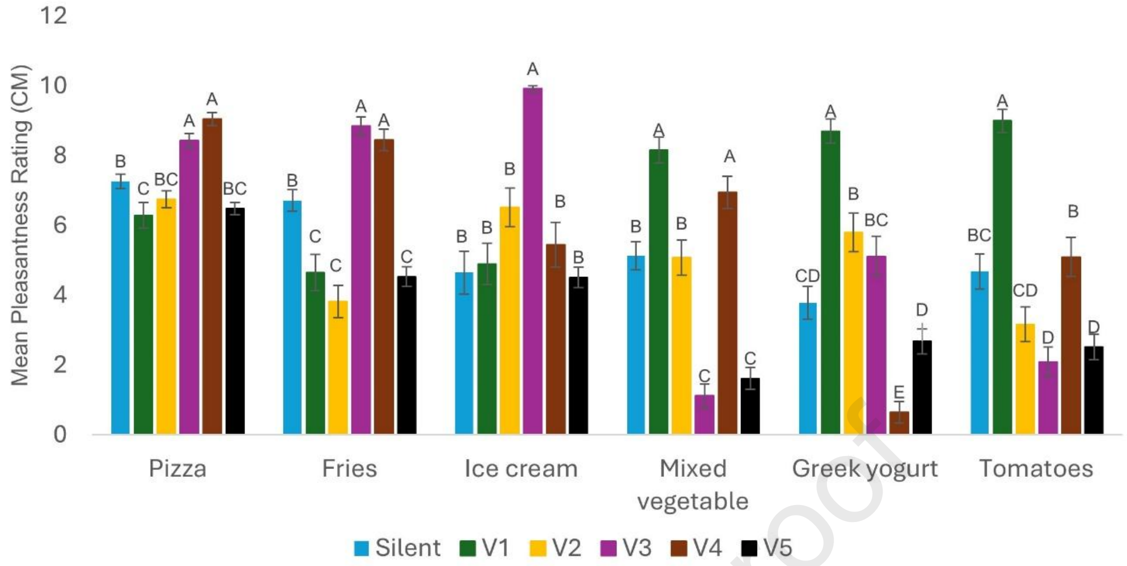
809 Appendix A. 9. participant ratings of healthy and unhealthy foods after consumption under six
810 conditions: “Silent” (control), “Lake Cruise” (V1), “Beach Scene” (V2), “Pool Party” (V3),

"Times Square Walkthrough" (V4) and "War Shelter" (V5). Results are expressed as mean ± SE. Different superscripts (^{A,B,C,D}) indicate significant differences ($p < .05$). a) overall pleasantness; b) food enjoyment; c) overall liking; d) perceived healthiness; e) flavour pleasantness; f) Appearance pleasantness of unhealthy items (pizza, fries, ice cream) and healthy items (mixed vegetables, Greek yoghurt, tomatoes).

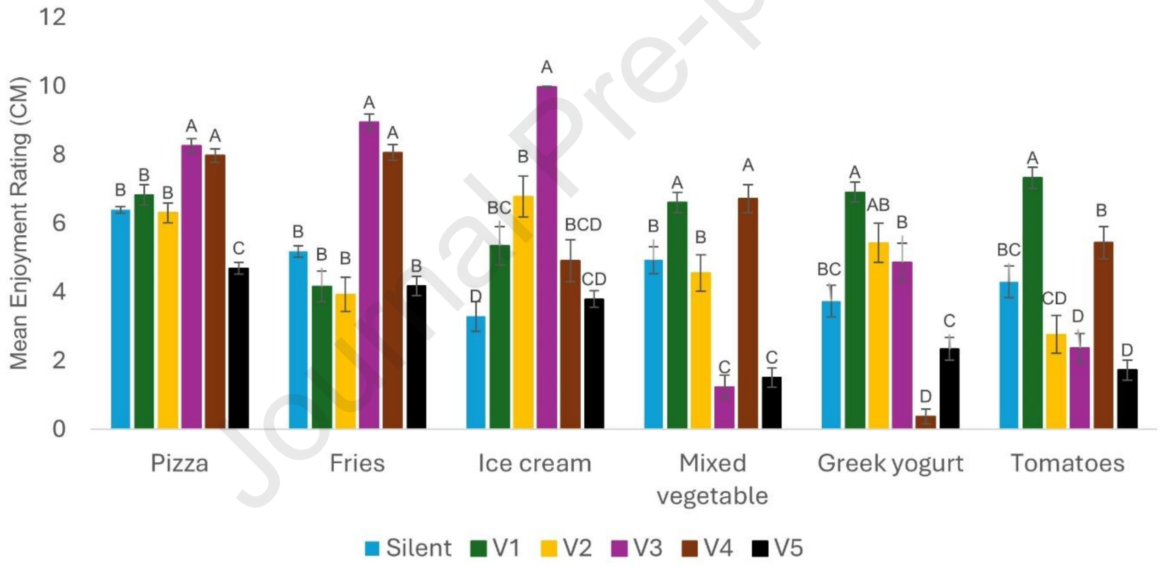
Healthy food items, including mixed vegetables, Greek yoghurt, and tomatoes, showed significantly higher ratings of pleasantness, enjoyment, satisfaction, and overall liking under the Lake Cruise condition compared with the Pool Party, Beach Scene, War Shelter, Times Square Walkthrough, and silent conditions.

In contrast, unhealthy food items (pizza, fries, and ice cream) exhibited significantly higher overall pleasantness ratings under the Times Square Walkthrough condition. Food satisfaction ratings were also significantly higher for healthy items, including mixed vegetables, banana, orange, and grapes, under the Lake Cruise condition.

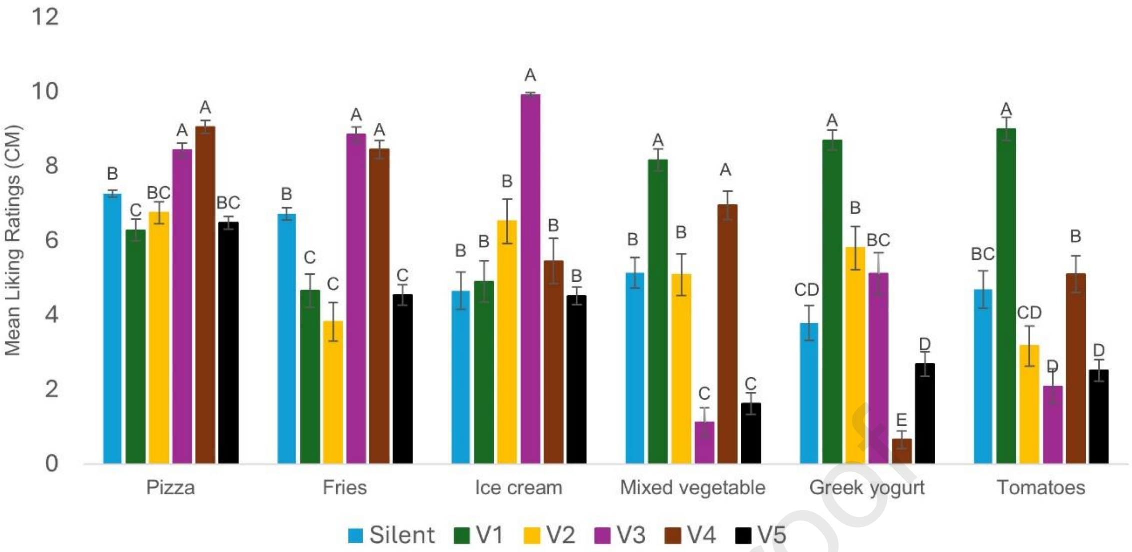
a) Overall pleasantness



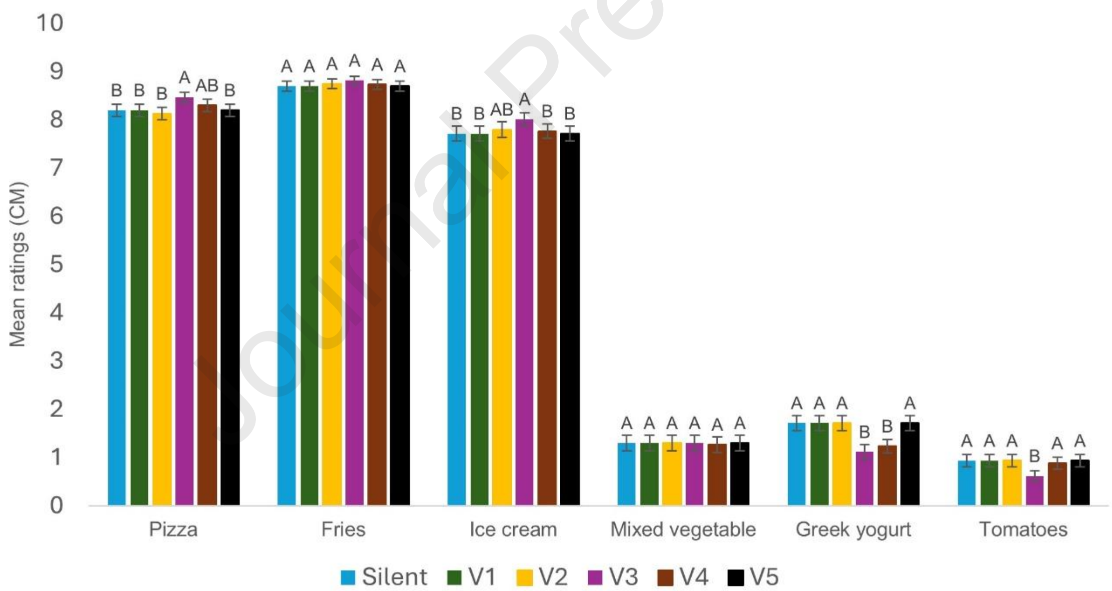
b) Enjoyment



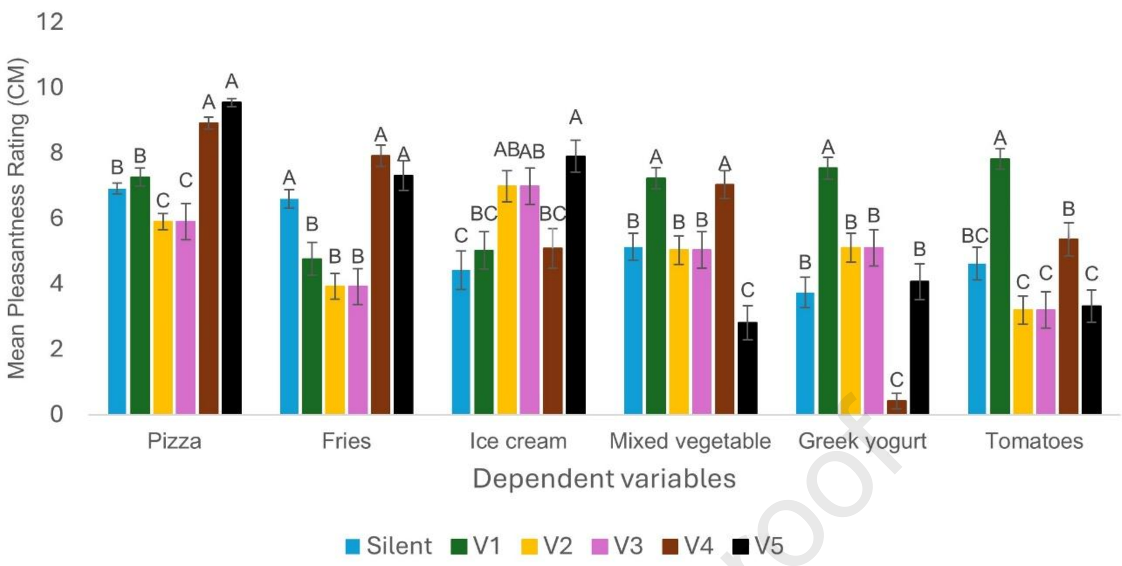
c) Overall liking



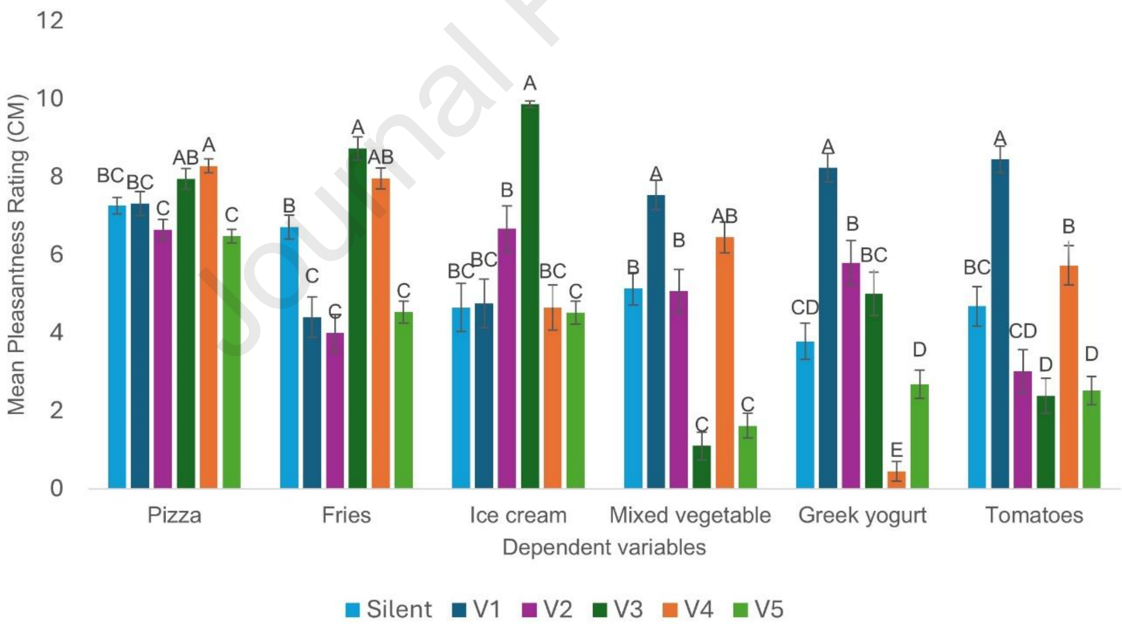
d) Perceive of healthiness

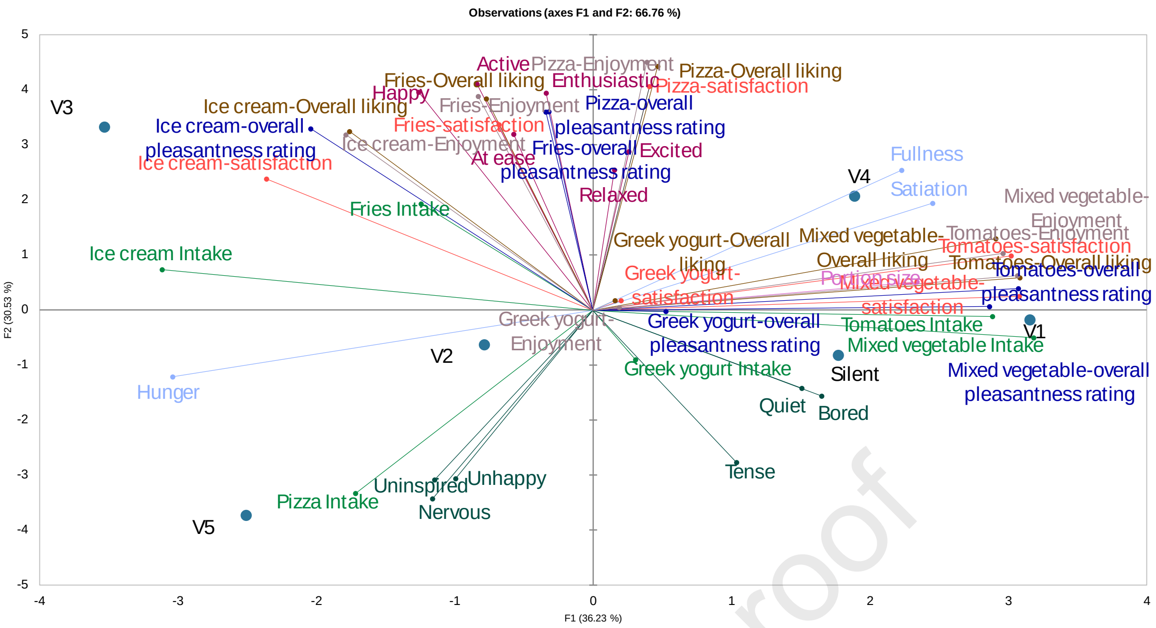


e) flavour pleasantness



f) Appearance pleasantness





830 Appendix A. 10. Multiple Factor Analysis (MFA) bi-plot illustrating changes in negative emotions (dark green), positive emotions (purple), intake of healthy and unhealthy foods (light green), and food-related ratings: hunger, fullness, and satiation (light blue), enjoyment (light brown), overall pleasantness (dark blue), overall liking of healthy and unhealthy items (dark brown), and satisfaction for healthy and unhealthy foods (red). Data represent participants consuming lunch under six conditions: “Silent” (control), “Lake Cruise (V1)” , “Beach Scene (V2)” , “Pool Party (V3)” , “Times Square Walkthrough(V4)” , and “War Shelter(V5)”

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Atmospheric Arousal vs. Health: Low-arousal, calm environments (such as those with nature-inspired imagery) reduce physiological stress and support mindful eating, leading to a significant increase in the intake and enjoyment of nutrient-dense foods like vegetables and yogurt.

The Overconsumption Risk of High Stimulation: Highly stimulating or stressful environments—characterized by high heart rates and skin conductance—weaken self-regulation. This shifts behavior toward the consumption of energy-dense "comfort foods" (e.g., pizza and fries) for emotional regulation rather than culinary appreciation.

Design for Satiety: Creating calm architectures with soft lighting, subdued soundscapes, and coherent layouts can enhance a guest's sensitivity to internal satiety cues. Conversely, visual clutter and high-motion digital displays can overload attention and lead to mindless, mechanical eating.

Strategic Culinary Planning: In high-arousal settings where excitement is intended, chefs and restaurateurs should implement portion control and balanced menu designs to mitigate the natural tendency toward overconsumption.

The authors declares no conflicts of interest