IAES International Journal of Artificial Intelligence (IJ-AI)
Vol. 15, No. 4, August 2026, pp. 3967~3980
ISSN: 2252-8938, DOI: 10.11591/ijai.v15.i4.pp3967-3980

A review of brain signal analysis in food perception studies

Harish S. Sinai Velingkar[1], Roopa R. Kulkarni[2], Prashant Patavardhan[3], Abdul Haq Nalband[4]
[1]Department of Electronics and Communication, Agnel Institute of Technology and Design, Visvesvaraya Technological University, Belagavi, India
[2]Department of Electronics and Communication Engineering, Dayananda Sagar Academy of Technology and Management, Belagavi, India
[3]Department of Electronics and Communication Engineering, RV Institute of Technology and Management, Bengaluru, India
[4]Department of Computer Science and Engineering (AI and ML), School of Engineering, Dayananda Sagar University, Bengaluru, India

Article Info

Article history:

Received Jul 4, 2025
Revised Jul 15, 2026
Accepted Jul 21, 2026

Keywords:

Brain computer interface
Cognitive neuroscience
Consumer behavior
Electroencephalography
Event related potentials
Multisensory perception
Neurophysiological

ABSTRACT

Food perception is more than just taste. It is a multisensory experience shaped by smell, texture, and even how the food looks. The human brain works to make sense of all these signals, influencing everything from cravings to food choices. This review looks at more than 40 studies that used electroencephalography (EEG) and other brainwave analysis tools to understand how to process food related stimuli. In order to identify patterns associated with attention, mood, and appetite, these studies looked at brain responses using techniques including event related potentials (ERPs) and spectral analysis. Current research shows that human desire for food, level of focus on it, and the feelings it evokes are all correlated with certain brain signals. However, majority of the studies investigated individual senses in isolation and focused on basic taste attributes such as sweet, salty, or bitter. The complexity of eating in real life, where several senses interact, is missed by this. Furthermore, a lot of research is lab based, short term, and does not represent real world situations. Future research must adopt practical, multimodal methods in order to fully understand how humans perceive food. Such studies could help improve food design, predict consumer behavior, and even support interventions for eating disorders.

Corresponding Author:

Harish S. Sinai Velingkar
Department of Electronics and Communication, Agnel Institute of Technology and Design
Visvesvaraya Technological University
Belagavi, India
Email: harishvelingkar@gmail.com

1. INTRODUCTION

Food is not just a source of energy; it is also a rich mental and sensory experience that the brain makes sense of by combining different signals. The human brain reacts to food through complicated neural dynamics because billions of neurons talk to each other through electrical activity. Electroencephalography (EEG) is a widely used non-invasive technique for recording brains electrical activity associated with perception, attention, and emotions. Different mental states are linked to different frequency bands. For example, beta waves (13–30 Hz) are most common during focused cognitive activity, especially in the front of the brain; alpha waves (8–13 Hz) are most common during relaxed alertness, often in the back of the brain; theta waves (4–8 Hz) are most common during drowsiness or light sleep; and delta waves (0.5–4 Hz) are most common during deep sleep [1], [2].

The physiological foundation for understanding how the brain reacts to everyday experiences like eating is provided by these neural rhythms. Sight, smell, taste, texture, and even human expectations of the food about to taste are all a part of the multimodal process of eating. Different kinds of sensory information stimulate different brain regions. For example, taste activates the insular cortex, texture activates the somatosensory areas and reward and value stimulates the orbitofrontal cortex (OFC). Together, these regions influence the perception and emotional reaction to food [3]. Instead of processing these attributes independently, the distributed neural networks combine them to produce a single eating experience [4]. The effect of sensory cues on emotional and cognitive responses related to food perception, consumer preference, and appetite regulation have been extensively studied using EEG and brain imaging techniques [5], [6].

Another commonly used tool in cognitive research is functional magnetic resonance imaging (fMRI). Using fMRI studies, we may gain a deeper understanding of how the brain interprets sensory and branding cues. Due to its relatively slower timing resolution (seconds), high power consumption, and a constrained motion limited scanner environment, the fMRI technique is less suitable for natural eating or real world sensory tasks, even though it offers high spatial detail (millimeter level), which is great for identifying specific areas [7].

EEG on the other hand is more reliable for researching rapid sensory reactions, taste memory and attention shifts since it records brain activity at millisecond speeds, uses relatively low power and can be used in a seated, movement tolerant arrangements. Studies combining EEG and fMRI show that the brain connectome patterns are repeatable from 1.5 T to 7 T scanners [8] and that EEG's strength resides in recording rapid neural changes [9] despite the fact that EEG is more sensitive to motion and muscle artefacts. Also majority of the research that is available focuses on basic lab stimuli and fundamental taste categories like sweet or bitter, despite the growing interest in brain research related to food. As demonstrated by Warnakulasooriya *et al.* [10] who used EEG and modern artificial intelligence (AI) techniques to assess the sensory qualities of food, recent approaches have also combined brainwave analysis with other computational tools for food evaluation.

However, real world meals are far more intricate. It is influenced by the situations in which human beings the food, the surroundings, the individual's personality and integrate numerous other sensory elements simultaneously [11]. This leads to major gaps in our understanding of how the brain processes complex, real world food experiences.

Studying these gaps is crucial for improving cognitive neuroscience as well as for managing disordered eating, developing nutrition plans, and designing healthier food alternatives. In order to examine how the brain interprets taste, smell, touch, and visual cues independently, and also in conjunction with a broader multisensory experience, this review combines findings from more than 40 peer-reviewed studies. The review is divided into three main sections: how various senses interact with one another, how multisensory integration functions and the new research gaps that need to be filled with a focus on the need for real world and ecologically valid investigations.

2. MATERIALS AND METHODS

The background for the EEG based investigations examined in this article is provided by Figure 1, which summarizes the key EEG frequency bands and the cognitive and behavioral states that are frequently associated with them. A typical EEG data collection protocol used in food perception research is shown in Figure 2, which includes electrode placement, sensory stimulation, signal acquisition, and subsequent signal analysis. In compliance with the preferred reporting items for systematic reviews and meta analyses (PRISMA) guidelines [12], a systematic literature review was conducted to identify studies related to neurophysiological processing of food related multisensory stimuli using EEG and other related methodologies.

2.1. Search strategy and data sources

A systematic search was conducted across the various platforms such as PubMed, Web of Science, and Scopus databases. Recent studies in multimodal neuroscience and EEG based food perception published between 2015 and 2025 were included in the search. The following terms and Boolean combinations were used: "EEG", "food perception", "taste", "texture", "smell", "visual cues", "multisensory integration", "event-related potentials", and "consumer behavior". This study used synonyms and variations to ensure that all relevant literature was covered.

2.2. Study selection and screening

290 records were found in the initial search: 150 from Scopus, 55 from Web of Science, and 85 from PubMed. After eliminating any duplicates, 210 unique articles remained. To eliminate research unrelated to food perception, multisensory processing, or neurophysiological data, this study further filtered the titles and abstracts. As a result, 60 irrelevant records were further eliminated. The whole text of the remaining 150 articles was screened.

2.3. Inclusion and exclusion criteria

Studies that explored food related sensory stimuli like taste, texture, smell, visual cues, or their combinations, used EEG or other comparable neurophysiological techniques, were published as peer-reviewed journal publications, and included any human subjects were included in the review. Studies that focused only on animal models, did not include food related stimuli, lacked neurophysiological measurements, or were purely review articles, editorials, or conference abstracts with incomplete data were excluded from this study.

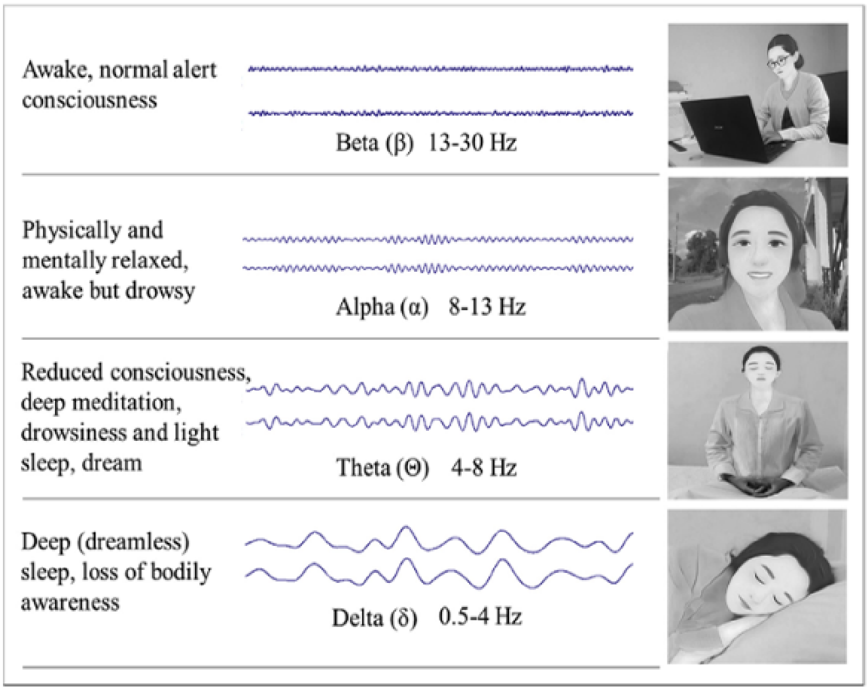


Figure 1. Correlation between EEG waveforms and emotional states

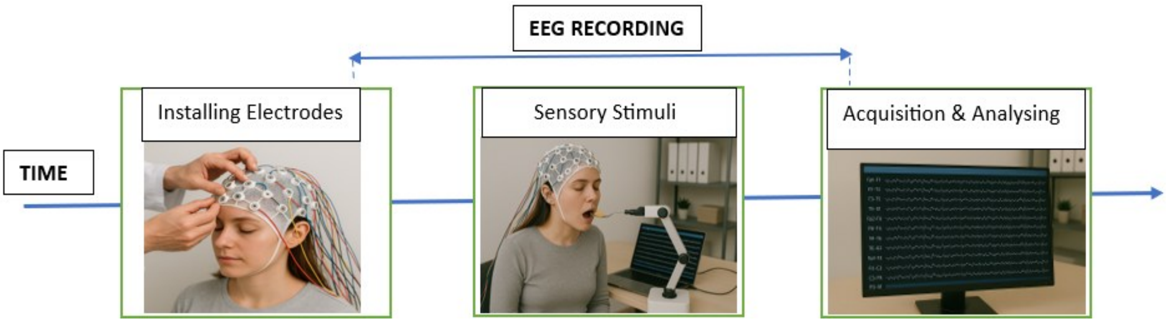


Figure 2. EEG data acquisition protocol for food perception studies

2.4. Eligibility and final selection

40 studies that satisfied all the eligibility requirements after full text evaluation were added to the final qualitative synthesis. Figure 3 shows the PRISMA flow diagram and illustrates the selection process. The clarity of the experimental design, participant information, EEG acquisition techniques, and result reporting were all examined to qualitatively examine the methodological quality of the included research.

Because the experimental procedures, outcome measurements, and analysis techniques varied across the different studies. Therefore, a quantitative meta-analysis was not feasible. Instead, a thematic qualitative synthesis was used to identify consistent neurophysiological patterns associated with multisensory perception of food.

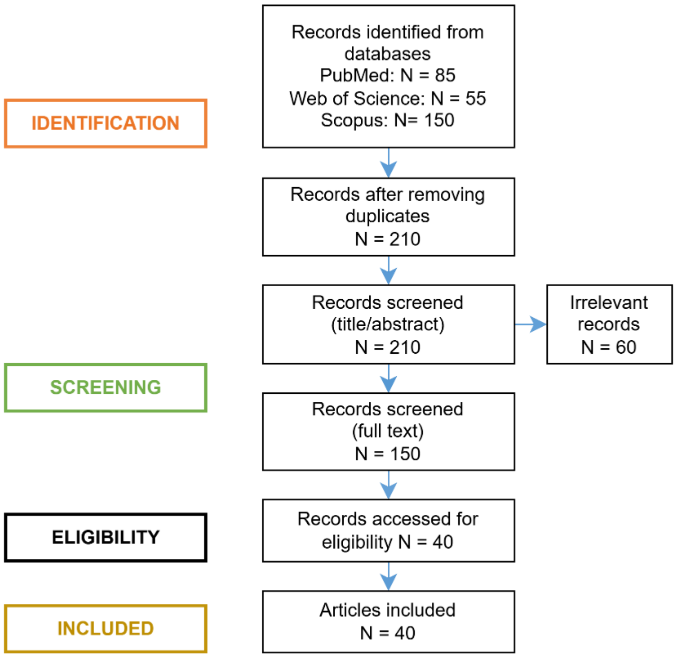


Figure 3. PRISMA flow diagram of the study screening and selection process

3. SENSORY PROCESSING OF TASTE AND TEXTURE OF FOOD IN THE HUMAN BRAIN

The gustatory cortex of the brain receives taste information from the tongue via nerves. The amygdala and hippocampus add emotional and memory-based layers to our taste sensations, while the OFC connects taste and reward thus modifying preferences based on hunger [3]. Taste perception has been demonstrated to affect advanced social and emotional processes, as Schaefer *et al.* [13] reported enhanced prosocial behavior following a sweet taste exposure highlighting the extensive cognitive implications of gustatory processing. It has also been demonstrated that oral stimulus related to taste influences the cognitive states. Even when no meal is consumed, Hosang *et al.* [14] demonstrated that washing the mouth with carbs alters how attention is processed. Our food choices also greatly influenced by its texture in Figure 4. Figure 4. Illustrates how Neuron 25 in the OFC responds strongly to slippery food textures, with a high inverse correlation to friction (r = -0.91) (Figure 4(a)). Its response to viscosity is weaker (r = 0.06) (Figure 4(b)), suggesting that lubricity plays a more critical role in texture-related brain activity [16].

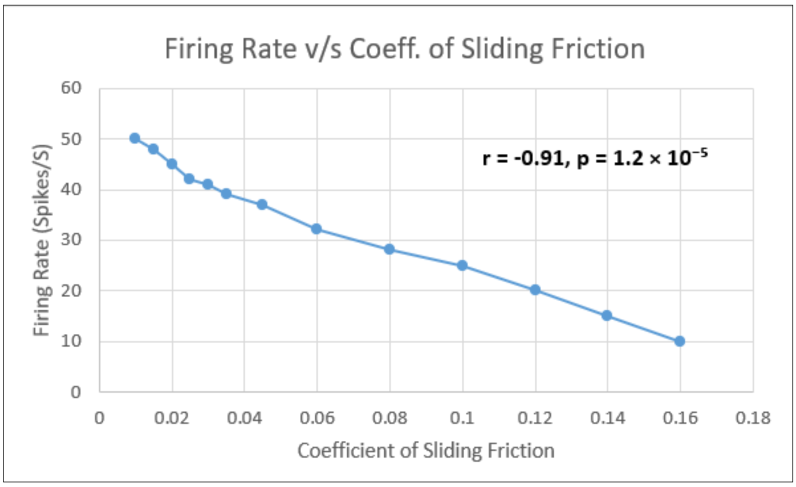
The somatosensory cortex, which deals with touch, is how our brain interprets sensations like crunchiness or creaminess of food. Not only can these textures improve the experience, but they also affect human perception of flavor and food choices. Low frequency oscillations are essential for gustatory processing according to recent the EEG research [15], with delta-band activity showing how the human brain encodes information linked to taste. For instance, because of their high sensory feedback, crunchy meals frequently cause stronger attention and brain responses. Rolls [16] discovered that the friction of the food altered the activity of a particular neuron in the OFC thus demonstrating the brain's fine tuning of food texture and reward.

Foods with complex or layered textures increase satisfaction levels by activating more brain regions for longer periods of time [17], [18]. Texture related food perception, which primarily stimulates somatosensory cortices but is modified by visual, auditory, and taste related inputs through integrative regions such the insula, supports multisensory and affective elements of eating [19]. Studies also reveal that taste and texture are processed by the brain together rather than as two distinct sensations. The insula, OFC, anterior cingulate cortex (ACC), and the amygdala are among the areas where multimodal integration takes place.

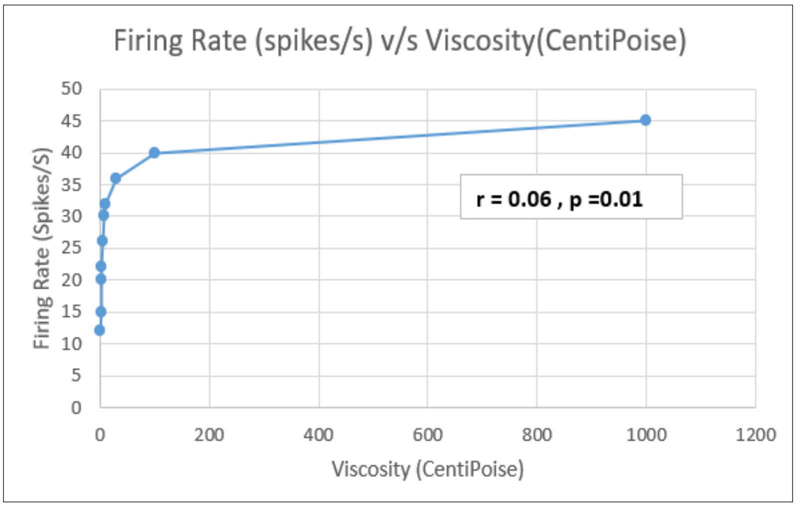
These regions are crucial for memory, emotion, and decision making. Studies have also shown that multisensory food cues generate integrated neural responses thus helping the brain combine sensory information such as taste and texture into a single perception of food [20]. Overlapping activation of the OFC and the anterior insula during flavor perception has also been reported suggesting their involvement in integrating taste, smell, and texture [21], [22]. Also, Kim and Kim [23] highlighted the insula's role in combining gustatory and somatosensory signals.

The amygdala, which adds emotional meaning to sensory experiences, influences texture preferences especially for rich, indulgent foods. These results suggest that our brain makes eating a smooth experience by combining different sensory signals into one tasty perception. Food preferences also depend on taste, texture, familiarity, and the past experiences.

High-fat and layered foods activate reward centers more intensely and stay interesting for longer, making them harder to resist [21]. Familiarity and emotional associations also enhance pleasure from eating [3], explaining cravings for processed, texture-rich foods like chips and fries [24], [25]. Children who are overweight or obese have also been found to exhibit different EEG activity patterns in response to food related stimuli than their peers who are of normal weight, suggesting that their cortical processing during food perception is altered [26].



(a)



(b)

Figure 4. OFC Neuron 25 responses to (a) friction and (b) viscosity

Researchers have learned a lot about how the brain processes simple tastes and textures in Table 1, but we still don't know much about how complex taste and textures like junk food for e.g. chips affect the brain in the real world. Such foods are of strong flavor, layered textures and have a lot of visual appeal but researchers haven't often looked into how they affect brain activity and the long-term eating habits caused by them. Studies show that even minor changes in texture can trigger different reactions in the brain. Need more real life, long-term studies with tools such as EEG and fMRI to really understand the consumer psychology.

Table 1. Comparative summary of literature on changes in brain waves for different tastes and flavors

Study	Key focus	Main findings	Brain response/techniques	Results and implications
Zhou *et al.* [3]	Spicy craving and reward	Spicy cravers show stronger brain response to chili food images	fMRI reward/visual regions	Visual spicy cues activate reward circuits, similar to addiction
Schaefer *et al.* [13]	Sweet taste and social behavior	Sweet taste increases prosocial responses	EEG/ERP affective markers	Taste influences emotion and social behavior, beyond sensory reward
Hosang *et al.* [14]	Attention modulation during carbohydrate mouth rinsing	Carbohydrate mouth rinsing alters attention and cognitive engagement	Behavioral attention measures + EEG/ERP markers	Suggests that taste/nutrient cues can modulate attentional processing even without ingestion
Wallroth *et al.* [15]	Taste information in EEG	Delta band carries taste-related signals	EEG spectral (delta activity)	Low-frequency EEG supports taste encoding
Rolls [16]	Texture and taste perception	Firing rate strongly linked to friction (r = -0.91); weaker for viscosity	OFC activity	Texture impacts flavor pleasantness; useful for appetite and obesity research
Andersen *et al.* [17]	Similar taste classification	EEG can differentiate perceptually close tastes	EEG + independent component analysis (ICA) preprocessing	Supports subtle taste discrimination when cleaned well
Peng *et al.* [18]	Color–texture congruence	Congruent color-texture cues increase gamma/theta activity and improve evaluation	EEG oscillations + behavior	Packaging texture can shape perceived reward and choice
Luo and Han [19]	Multisensory flavor integration	Flavor shaped by senses + personal factors	Theoretical model	Flavor is psychological, influenced by environment and past experiences
Stuldreher *et al.* [20]	Taste-visual conditioning	Taste pairings enhanced visual neural responses; increased delta/theta	EEG (N2-P3 waves, delta/theta bands)	Taste-visual learning induces long-term sensory brain changes
Han *et al.* [21]	Sweetness sensitivity and fat food	Sweet-sensitive individuals: stronger insula activity, prefer high-carb foods	EEG, insular cortex	Sweet sensitivity shapes eating behavior and food preferences
Kosling *et al.* [22]	Obesity and neural food reactivity	Obese children: increased frontal beta, decreased parietal alpha with high-calorie cues	EEG (frontal/parietal activity)	Distinct neural markers for overeating tendencies
Kusunoki *et al.* [24]	Eating and emotion	EEG bands shift with emotion during eating	EEG frequency domain	Emotional context changes feeding signatures
Songsamoe *et al.* [25]	Consumer emotion to food	EEG tracks physiological and emotional reactions to food	EEG spectral + ERP (review context)	EEG useful for consumer neuroscience outside labs
Baines *et al.* [26]	Reward timing and body mass index (BMI)	Overweight groups show altered reward response to pleasant taste cues	EEG + ERP reward components	BMI affects neural reward phases and attention to pleasant food
Kim and Kim [23]	Makgeolli taste analysis	Brainwaves linked to bitterness; unsterilized samples preferred	Brainwave analysis	Brain-based systems help evaluate and scale beverage preferences

4. SENSORY AND NEURAL PROCESSING OF VISUAL FOOD CUES IN THE HUMAN BRAIN

Images of food trigger a broad brain network that links memories, feelings, and desires. Using EEG methods like multifractal detrended fluctuation analysis (MFDFA) and multifractal detrended cross-correlation analysis (MFDXA), Roy *et al.* [27] discovered that blue colored food images triggered the most complex brain activity. These changes were reflected in distinct patterns of brain activity indicating enhanced communication between brain regions and a prolonged processing of sensory information. In addition to taste and texture, visual cues such as packaging and labeling also play an important role in shaping neural responses to food. Spence *et al.* [4] demonstrated that color contrast can influence perceived taste and increase the perceived appeal of food. David *et al.* [28] found that while some health warnings reduced the attractiveness of food products, others increased their appeal, emphasizing the complex role of visual cues in shaping the food preferences. Food choices depend on more than just sensory characteristics such as taste and texture. Economic incentives, cultural influences also contribute in the decision-making process. Banerjee *et al.* [1] showed that rebates made healthier food options more appealing and activated reward related brain regions, making these choices easier for participants. In another study, Lim *et al.* [29] examined traditional Korean dinners in Figure 5 and discovered that people's enjoyment of the foods increased with their complexity and familiarity. Stronger reward reactions and reduced mental effort were shown in brain scans indicating that our brain switches from comparing the options to just savoring the moment when eating feels familiar and pleasant in Figure 6. Figure 5. illustrates how participants liking scores improved as Korean dishes became more complex (M1–M4) thus indicating a greater preference for visual and flavor richness throughout 80 randomized trials [29]. Figure 6 shows stronger brain responses to the visuals of complex meal 4 across key ERP time windows indicating increased sensory engagement with food cues [29].

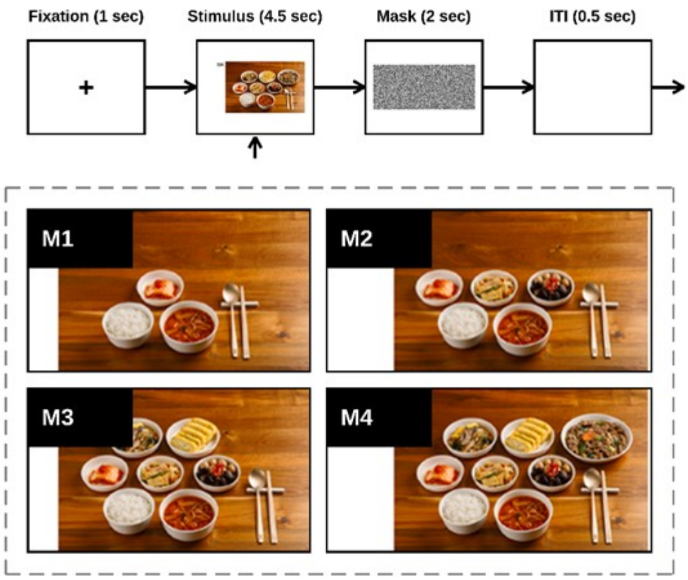


Figure 5. Experimental food stimuli with increasing meal complexity

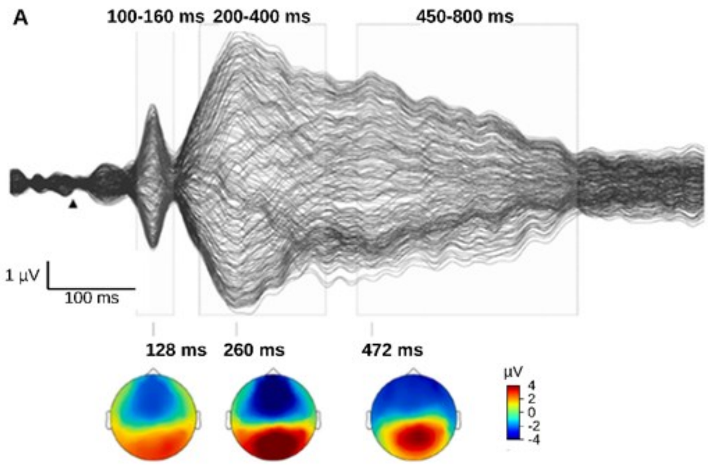


Figure 6. ERP responses to food stimuli

According to Zhou *et al.* [3], those who enjoyed spicy food exhibited higher levels of brain activity connected to food cravings and react faster to the visuals of spicy food, indicating that their brain is more sensitive to the spice level. The brain responds rapidly to visual food cues, even before any conscious evaluation of food takes place. Vermeir and Roose [30] reviewed how visual design elements such as color, shape and the layout influences the food choices through psychological and behavioral mechanisms while also identifying important gaps and future research directions in this field. In another different study, Vartanian *et al.* [31] demonstrated that visually appealing foods can trigger brain activity patterns resembling those observed in addictive behaviors, particularly when an individual is hungry and has a greater body weight. Schubert *et al.* [32] showed that the brain responds to the healthiness of food even before consciously evaluating its taste. The study reported that health related information was identified from the food images with approximately 77% accuracy, while taste related information was recognized with about 71% accuracy during the evaluation process. These findings suggest that health related neural processing precedes the conscious assessment of flavor while making food choices. It also shows how deeply food images can influence our brain's emotional and decision-making systems.

A brief overview of how the visual food cues affect human brain activity specifically in areas linked to emotion, reward, and decision making is provided in Table 2. Our brain frequently reacts to food even before we realize it. The amygdala and insula can indicate repulsion to food, whereas areas like the OFC assess how appetizing the food appears. According to some research, similar to addiction, regions of the brain linked to cravings are activated in reaction to specific images. However, most of this research has been conducted in controlled laboratory environments or within a specific cultural setting. Future studies need to look into how different real life food images in real life scenarios affect brain responses over long periods of time.

Table 2. Summary of studies on neural responses to visual food stimuli

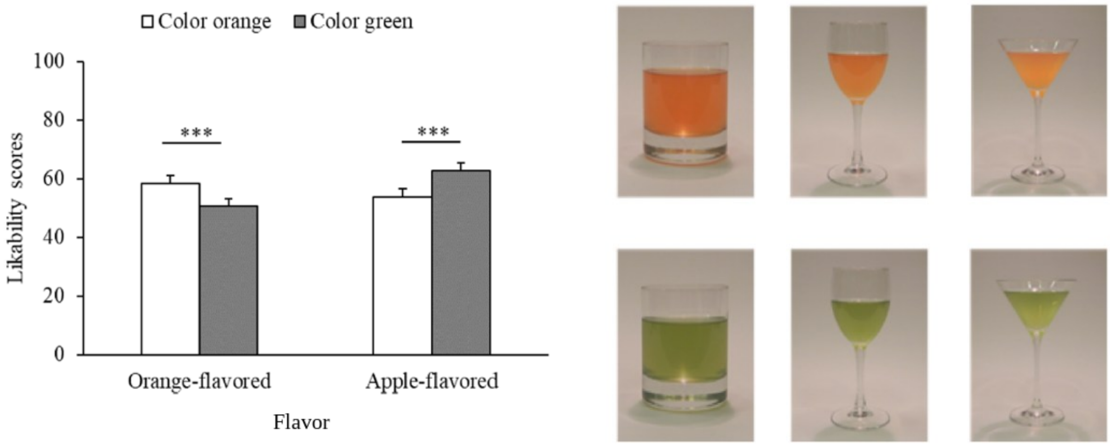
Study	Key focus	Main findings	Brain response/techniques	Results and implications
Roy *et al.* [27]	Color and brain activity	Blue color triggered highest neural complexity	EEG, MFDFA/MFDXA, frontal, occipital, and parietal	Color significantly shapes the brain dynamics
Spence *et al.* [4]	Visual aesthetics of food	Color contrast/background affects perceived deliciousness	EEG and reward regions	Visuals can influence healthier food choices
David *et al.* [28]	Food labeling and emotion	Health warnings reduced appeal but red labels backfired	EEG, ERPs, and emotional modulation	Label design affects food appeal and policy impact
Banerjee *et al.* [1]	Fiscal incentives and food choice	Rebates boosted healthier choices and reduced mental effort	EEG, fMRI, and reward regions	Fiscal tools encourage better food decisions
Lim *et al.* [29]	Meal complexity and liking	Complex meals increased liking and reward activity	EEG, Insula, OFC, and dorsolateral prefrontal cortex (dlPFC)	Complexity enhances reward and preference circuits
Zhou *et al.* [3]	Craving spicy foods	Cravers showed faster, stronger neural response	fMRI, Insula, ACC, and Putamen	Craving linked to addiction-like brain activity
Vermeir and Roose [30]	Visual design cues and food choice	Visual elements (color, layout, and imagery) influence food decisions via attention, affect, cognition, and motivation	Narrative review of behavioral and psychological studies	Visual design shapes perceptions and attitudes, affecting food choice behaviour and highlighting gaps for future research
Vartanian *et al.* [31]	Weight and hunger effects on neural food cue processing	Food visuals activate reward and visual areas	fMRI meta-analysis	Shows shared reward/visual processing, with some differences by BMI and hunger
Schubert *et al.* [32]	Taste vs. health in decisions	Health cues processed earlier than taste	EEG, OFC, cingulate, and insula	Challenges assumption that taste dominates food choice

5. SENSORY AND NEURAL PROCESSING OF MULTISENSORY STIMULI IN THE HUMAN BRAIN

Our brain's response to food isn't just about taste or looks but it's shaped by a mix of smell, texture, packaging, and even mood or tiredness, in turn deciding what we choose or crave. Yang *et al.* [33] found that taste doesn't just help us recognize food, it also stirs emotional brain responses, influencing how much we enjoy it and the choices we make in Figure 7. Figure 7. Illustrates how visual presentation, specifically the color of drinks (Figure 7(a)) and shape of glassware (Figure 7(b)), significantly influenced brain responses and increased positive ratings due to color-flavor congruency [33]. In the experiment conducted, participants preferred drinks when the color matched the expected flavor, and drinks served in wine or cocktail glasses were rated tastier showing how glass shape and color influences our taste perception.

In another study, Yagyu *et al.* [34] found that flavored chewing gum altered the global complexity of multichannel EEG activity in a manner that unflavored gum did not. This shows how the combination of taste and smell increases brain activity. The brain's function in integrating the sensory inputs is highlighted also by Maeda and Yoshimura [35] who reported an increased theta band activity during mismatched olfactory taste stimulation. Event related potentials (ERPs) have been widely used to study brain responses associated with reward and food related cognitive processing. These measures provide useful insights into how known food cues become linked with attention and motivational responses [36]. ERPs are particularly useful for stimulus onset analysis because they capture rapid and time locked brain responses occurring when a sensory stimulus like taste or texture is presented. On the other hand, spectral analysis provides insights into neural activity over much longer periods of time and can help examine processes related to perception of texture, cravings and taste memory through changes in frequency band activity [37].

Byrne *et al.* [38] observed an increased gamma activity when visual food cues matched the perceived taste. In contrast for mismatched cues, such as viewing broccoli while tasting sugar evoked the N400 responses which are generally associated with conflicting sensory information. These studies suggest that taste is rarely experienced on its own while the brain continuously combines what we see and what we taste. This interaction between taste and visual cues can influence a person's food perception. Domracheva and Kulikova [39] also supported this idea by identifying distinct EEG patterns which are associated with perceived similarities between food products during a taste visual integration task.



(a) (b)

Figure 7. Visual presentation of (a) effect of drink color and (b) glass shape on likability ratings

According to Christoffersen *et al.* [40], the human brain reacts not just to taste but also to the appearance of food and past experiences with it. The human brain uses that visual memory to influence and decide how it would respond to a particular food in the future if have frequently perceived it as either pleasant or unpleasant. In a similar study, Wolz *et al.* [41] found that individuals with binge eating tendencies showed stronger brain responses to the sight and smell of chocolate, which were also associated with increased craving and attention. Such findings show how the human brain recalls previous visual and sensory experiences to influence responses to food. Internal factors such as hunger and hormonal states also influence how the brain responds to food, beyond the effects of visual, olfactory, and taste cues. Janet *et al.* [42] found that hunger was associated with an increased activity in the brain regions such as the ventromedial prefrontal cortex and striatum when the participants were exposed to food cues. Similarly, Lowe *et al.* [43] also found that using brain stimulation to disrupt the left dorsolateral prefrontal cortex led to alterations in the EEG (stronger N2 and P3), which also suggested a decrease in the cognitive control as well as an increase in the consumption of high calorie items.

Flavor is not just determined by taste alone rather it develops through the combined influence of multiple other senses. Studies have shown that these sensory systems do not operate independently as even visual and auditory cues can influence the eating experience. Jing *et al.* [44] found that pleasant background sounds while consuming sweets increased both neural activity and perceived enjoyment. Similarly, Rodriguez *et al.* [45] and Jusienė *et al.* [46] reported that people tend to consume more food while watching television than while eating without such distractions. Such findings suggest that audiovisual distractions may influence attention during eating and contribute to an increased consumption of food. The feel of the packaging and financial incentives like discounts can also significantly influence food perception and brain responses. Smooth textures are generally linked with healthier foods, while discounts can alter neural reward processing in low income groups [47]. Lastly, the sleep quality can also influence taste preferences. Deeper sleep reduced sweet cravings without altering smell sensitivity [48].

Table 3 summarizes how the brain processes multisensory food cues like taste, smell, texture, and visuals. EEG and fMRI studies reveal that regions like the orbitofrontal and prefrontal cortex integrate these signals, which are influenced by our emotions, hunger, memory, and sleep. These results show that taste is a very personal and brain based experience, but most studies so far have only looked at small, similar groups of people in short lab experiments [49], [50]. To truly understand how human senses shape what eat, future research needs to include more diverse participants, real life eating situations and long-term observations.

This gap has begun to receive greater attention in the recent years. Recent studies have increased the scope of EEG based food perception research by providing broader reviews of consumer neuroscience [51] demonstrating that the neurocognitive processing of texture and other sensory attributes span across a wide range of foods including the processed products [52]. They have also shown that real world eating environments produce neurophysiological and behavioral responses that are different from those observed in a controlled laboratory setting [53] while summarizing recent advances in EEG signal processing and analytical techniques for studying gustatory perception [54]. These findings support the need for more ecologically valid and multisensory research approaches thus reinforcing the direction of the present review. The summary of all the studies and references included in the qualitative analysis is shown in Table 4.

Table 3. Comparison of studies on neural dynamics of multisensory integration and brain responses to combined sensory stimuli

Study	Key focus	Main findings	Brain response/techniques	Results and implications
Yang *et al.* [33]	Brain activity in taste preference	Brain distinguishes taste qualities and pleasantness	EEG, frequency bands, temporal dynamics	Taste linked to specific brain patterns; further study needed on timing
Yagyu *et al.* [34]	Flavor of chewing gum and EEG complexity	Flavored gum alters global EEG complexity vs. unflavored gum	Multichannel EEG, global complexity measures	Flavor cues from gum alter global brain-signal complexity
Maeda and Yoshimura [35]	Olfactory–taste mismatch effects	Theta activity rises during mismatched smell–taste	EEG spectral (theta band)	Shows mismatch drives higher cognitive load in sensory hubs
Forester *et al.* [36]	ERP methods for reward processing	ERP markers are sensitive to food-related reward and attention	EEG-based ERP components (P2, P3/LPP)	Supports ERPs as effective tools for studying food-related reward and cue processing
Campos *et al.* [37]	Principal ERP extraction (pERP-RED)	Reduces ERPs to core waveforms across tasks/subjects	ERP reduction + cross-electrode estimation	Supports scalable ERP analysis across subjects and electrodes.
Byrne *et al.* [38]	EEG measures in neuromarketing	Identifies common EEG markers linked to attention, emotion, and rewardpower; mismatch evoked N400	EEG spectral analysis, ERP components	Highlights EEG as a useful tool for assessing consumer and food-related neural responses
Domracheva and Kulikova [39]	Taste–visual congruence/mismatch	Congruence boosts induced gamma; mismatch evokes N400-like	EEG + ERP (gamma, N400-like deflection)	Confirms early neural signatures of sensory congruence vs confusion.
Christoffersen *et al.* [40]	Visuo-gustatory conditioning	Conditioned visuals enhanced cortical responses, right dominance	visual evoked potential (VEP), N2-P3 amplitude	Visual-taste pairings modulate sensory brain responses
Wolz *et al.* [41]	Olfactory and visual food cues in cravings	Binge-eaters showed stronger craving, increased N2 and LPP	EEG, N2, LPP amplitudes	Craving linked to heightened brain reactivity in disorder group
Janet *et al.* [42]	Appetite regulation via food stimuli	Hunger modulated brain activation in food valuation regions	fMRI, dorsomedial prefrontal cortex (dmPFC), ventromedial PFC (vmPFC), and striatum	Specific areas control hunger and decision-making
Lowe *et al.* [43]	dlPFC's role in controlling cravings	Disrupted dlPFC led to increased high-calorie intake	Repetitive transcranial magnetic stimulation (rTMS), EEG, N2, P3b, P3a	dlPFC involved in inhibiting food consumption
Jing *et al.* [44]	Effect of music context on food preference	Different music types modulate neural responses to food stimuli	ERP analysis (N2, P2 components)	Shows that auditory context influences food preference through neural processing mechanisms
Rodriguez *et al.* [45]	Impact of screen use during eating on snack consumption	Watching TV while eating increases snack consumption; smartphone use does not	Behavioral intake measures (no neural measures)	Indicates that sustained audiovisual distraction (TV) may disrupt eating control, while brief smartphone use does not
Jusienė *et al.* [46]	Screen distraction during meals	TV use links to less regulated eating	Behavioral survey and screen-eating context	Screen distraction associates with weaker eating self-control.
Peng *et al.* [47]	Packaging texture and health perception	Smooth texture linked to healthier choices, stronger P300 response	ERP, brief implicit association test (BIAT), P300, and late negative component (LNC)	Subtle tactile cues influence food expectations
Szczygiel *et al.* [48]	Sleep and sweet preference	More sleep linked to reduced preference for sweetness	EEG	Sleep patterns subtly shape taste preferences

Table 4. Summary of studies and references included in the qualitative analysis

	Taste and flavour			Visual stimuli			Multisensory stimuli	
Study	Reference	Table/figure	Study	Reference	Table/figure	Study	Reference	Table/figure
1	Zhou *et al.* [3]	1	1	Roy *et al.* [27]	2	1	Yang *et al.* [33]	3/7
2	Schaefer *et al.* [13]	1	2	Spence *et al.* [4]	2	2	Yagyu [34]	3
3	Hosang *et al.* [14]	1	3	David *et al.* [28]	2	3	Maeda and Yoshimura [35]	3
4	Wallroth *et al.* [15]	1	4	Banerjee *et al.* [1]	2	4	Forester *et al.* [36]	3
5	Rolls [16]	1/4	5	Lim *et al.* [29]	2/5-6	5	Campos *et al.* [37]	3
6	Andersen *et al.* [17]	1	6	Zhou *et al.* [3]	2	6	Byrne *et al.* [38]	3
7	Peng *et al.* [18]	1	7	Vermeir and Roose [30]	2	7	Domracheva and Kulikova [39]	3
8	Luo and Han [19]	1	8	Vartanian *et al.* [31]	2	8	Christoffersen *et al.* [40]	3
9	Stuldreher *et al.* [20]	1	9	Schubert *et al.* [32]	2	9	Wolz *et al.* [41]	3
10	Han *et al.* [21]	1				10	Janet *et al.* [42]	3
11	Kosling *et al.* [22]	1				11	Lowe *et al.* [43]	3
12	Kusunoki *et al.* [24]	1				12	Jing *et al.* [44]	3
13	Songsamoe *et al.* [25]	1				13	Rodriguez *et al.* [45]	3
14	Baines *et al.* [26]	1				14	Jusienė *et al.* [46]	3
15	Kim and Kim [23]	1				15	Peng *et al.* [47]	3
						16	Szczygiel *et al.* [48]	3

6. CONCLUSION

This review shows that the brain integrates smell, vision, touch, and memory of food into a single experience, making the food perception more than just the taste. These sensory inputs are combined by the OFC, insula, and prefrontal cortex, which are the crucial brain regions that influence our desire or avoidance of particular meals. In addition, these processes are influenced by external factors like food presentation and packaging as well as internal factors like hunger and mood. From a practical perspective, understanding how the brain responds to food can help designers and manufacturers develop the food products, packaging and marketing cues that better align with the consumers expectation and preference. This knowledge also has important applications in public health, where a better understanding of sensory cues may support dietary interventions, encourage healthier food choices and help to address unhealthy eating behaviors. A major limitation of the existing research is that it relies on simplified food stimuli, highly controlled laboratory settings and narrowly defined participant groups. Although these conditions are useful for understanding specific responses, they may not fully represent how people actually experience food in everyday life, particularly in the case of processed foods and culturally diverse diets. This limits the real-world applications of many findings and highlights the need for studies which need to be conducted in a more natural eating environment. Portable EEG devices and wearable sensors are making it easier to study food related responses in everyday settings rather than only in controlled laboratories. Combining brain data with AI and machine learning techniques may also help to improve the prediction of food preferences and eating behaviors. Further progress in this field will depend on collaboration across neuroscience, psychology, nutrition and marketing to develop a larger understanding of how people perceive and choose food. Finally, ethical considerations should remain as an important part of consumer neuroscience and neuromarketing as the fields continue to develop. These technologies should be used to inform and support consumers with transparency rather than manipulate their choices thus making responsible use of neural data. The future of this field will depend not only on advances in the methods and technology but also on the ethical and responsible manner in which the research is conducted.

FUNDING INFORMATION

This research received no external funding.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Harish S.Sinai Velingkar	✓	✓			✓	✓	✓	✓	✓					
Roopa R. Kulkarni	✓	✓		✓				✓		✓	✓	✓	✓	
Prashant Patavardhan	✓		✓	✓						✓	✓	✓	✓	
Abdul Haq Nalband	✓			✓						✓		✓		

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The author declares no conflict of interest.

DATA AVAILABILITY

This study is a literature review and does not include any original data. All sources of information used in the review are publicly available and cited within the manuscript. No new datasets were generated or analyzed during this study.

REFERENCES

[1] T. Banerjee, V. Chattaraman, H. Zou, and G. Deshpande, “A neurobehavioral study on the efficacy of price interventions in promoting healthy food choices among low socioeconomic families,” *Scientific Reports*, vol. 10, no. 1, Sep. 2020, doi: 10.1038/s41598-020-71082-y.

[2] M. Priyadarshani, P. Kumar, K. S. Babulal, D. S. Rajput, and H. Patel, “Human brain waves study using EEG and deep learning for emotion recognition,” *IEEE Access*, vol. 12, pp. 101842–101850, 2024, doi: 10.1109/ACCESS.2024.3427822.

[3] Y. Zhou, X. Gao, D. M. Small, and H. Chen, “Extreme spicy food cravers displayed increased brain activity in response to pictures of foods containing chili peppers: an fMRI study,” *Appetite*, vol. 142, 2019, doi: 10.1016/j.appet.2019.104379.

[4] C. Spence, K. Motoki, and O. Petit, “Factors influencing the visual deliciousness/eye-appeal of food,” *Food Quality and Preference*, vol. 102, 2022, doi: 10.1016/j.foodqual.2022.104672.

[5] M. Klug and K. Gramann, “Identifying key factors for improving ICA-based decomposition of EEG data in mobile and stationary experiments,” *European Journal of Neuroscience*, vol. 54, no. 12, pp. 8406–8420, 2021, doi: 10.1111/ejn.14992.

[6] N. Panigrahi and S. P. Mohanty, “Protocol and process of EEG data acquisition,” *Brain Computer Interface*, pp. 81–95, 2022, doi: 10.1201/9781003241386-5.

[7] I. C. Tang *et al.*, “Using functional magnetic resonance imaging (fMRI) to analyze brain region activity when viewing landscapes,” *Landscape and Urban Planning*, vol. 162, pp. 137–144, 2017, doi: 10.1016/j.landurbplan.2017.02.007.

[8] R. F. Ahmad, A. S. Malik, N. Kamel, and F. Reza, “EEG-fMRI combination for better understanding of brain functions: pros and cons,” in *IEEE 2015 International Conference on Signal and Image Processing Applications, ICSIPA 2015 - Proceedings*, 2016, pp. 278–281, doi: 10.1109/ICSIPA.2015.7412204.

[9] J. Wirsich *et al.*, “The relationship between EEG and fMRI connectomes is reproducible across simultaneous EEG-fMRI studies from 1.5T to 7T,” *NeuroImage*, vol. 231, 2021, doi: 10.1016/j.neuroimage.2021.117864.

[10] K. Warnakulasooriya, J. Bandara, and B. H. Sudantha, “Sensory evaluation of foods using modern AI techniques and brain wave analysis,” in *Proceedings of International Conference on Image Processing and Robotics, ICIPRoB 2020*, 2020, doi: 10.1109/ICIP48927.2020.9367340.

[11] M. Heidari, Y. K. Jokar, S. Madani, S. Shahi, M. S. Shahi, and M. Goli, “Influence of food type on human psychological–behavioral responses and crime reductio,” *Nutrients*, vol. 15, no. 17, 2023, doi: 10.3390/nu15173715.

[12] M. J. Page *et al.*, “The PRISMA 2020 statement: an updated guideline for reporting systematic reviews,” *Systematic Reviews*, vol. 10, no. 1, 2021, doi: 10.1186/s13643-021-01626-4.

[13] M. Schaefer, A. Kühnel, F. Schweitzer, F. Rumpel, and M. Gärtner, “Experiencing sweet taste is associated with an increase in prosocial behavior,” *Scientific Reports*, vol. 13, no. 1, 2023, doi: 10.1038/s41598-023-28553-9.

[14] T. J. Hosang, S. Laborde, A. Löw, M. Sprengel, N. Baum, and T. Jacobsen, “How attention changes in response to carbohydrate mouth rinsing,” *Nutrients*, vol. 15, no. 13, 2023, doi: 10.3390/nu15133053.

[15] R. Wallroth, R. Höchenberger, and K. Ohla, “Delta activity encodes taste information in the human brain,” *NeuroImage*, Apr. 13, 2018, doi: 10.1101/300194.

[16] E. T. Rolls, “The texture and taste of food in the brain,” *Journal of Texture Studies*, vol. 51, no. 1, pp. 23–44, 2020, doi: 10.1111/jtxs.12488.

[17] C. A. Andersen *et al.*, “EEG discrimination of perceptually similar tastes,” *Journal of Neuroscience Research*, vol. 97, no. 3, pp. 241–252, 2019, doi: 10.1002/jnr.24281.

[18] Y. Peng, Y. Sun, and X. Wan, “Influence of the crossmodal congruency between color and flavor on product evaluations: evidence from behavioral and oscillatory brain responses,” *Food Quality and Preference*, vol. 97, 2022, doi: 10.1016/j.foodqual.2021.104480.

[19] L. Luo and P. Han, "Assessing food-evoked emotions using functional magnetic resonance imaging: a systematic review," *Food Quality and Preference*, vol. 108, 2023, doi: 10.1016/j.foodqual.2023.104877.

[20] I. V. Stuldreher, D. Kaneko, H. Hiraguchi, J. B. F. V. Erp, and A. M. Brouwer, "EEG measures of attention toward food-related stimuli vary with food neophobia," *Food Quality and Preference*, vol. 106, 2023, doi: 10.1016/j.foodqual.2022.104805.

[21] P. Han, M. Mohebbi, H. S. Seo, and T. Hummel, "Sensitivity to sweetness correlates to elevated reward brain responses to sweet and high-fat food odors in young healthy volunteers," *NeuroImage*, vol. 208, 2020, doi: 10.1016/j.neuroimage.2019.116413.

[22] C. Kösling, L. Schäfer, C. Hübner, C. Sebert, A. Hilbert, and R. Schmidt, "Food-induced brain activity in children with overweight or obesity versus normal weight: an electroencephalographic pilot study," *Brain Sciences*, vol. 12, no. 12, 2022, doi: 10.3390/brainsci12121653.

[23] Y. S. Kim and Y. S. Kim, "Biometrics analysis and evaluation on Korean Makgeolli using brainwaves and taste biological sensor system," *BioMed Research International*, 2015, doi: 10.1155/2015/918631.

[24] S. Kusunoki *et al.*, "Relationships between feeding behaviors and emotions: an electroencephalogram (EEG) frequency analysis study," *The journal of physiological sciences* , vol. 73, no. 1, 2023, doi: 10.1186/s12576-022-00858-w.

[25] S. Songsamoe, R. Saengwong-ngam, P. Koomhin, and N. Matan, "Understanding consumer physiological and emotional responses to food products using electroencephalography (EEG)," *Trends in Food Science and Technology*, vol. 93, pp. 167–173, 2019, doi: 10.1016/j.tifs.2019.09.018.

[26] S. Baines, I. S. Hensels, and D. Talmi, "An EEG study on the effect of being overweight on anticipatory and consummatory reward in response to pleasant taste stimuli," *Physiology and Behavior*, vol. 252, 2022, doi: 10.1016/j.physbeh.2022.113819.

[27] S. Roy *et al.*, "Brain response to color stimuli: an EEG study with nonlinear approach," *Cognitive Neurodynamics*, vol. 15, no. 6, pp. 1023–1053, 2021, doi: 10.1007/s11571-021-09692-z.

[28] I. A. David *et al.*, "Use of event-related potentials to measure the impact of front-of-package labels on food-evoked emotion," *Food Quality and Preference*, vol. 111, 2023, doi: 10.1016/j.foodqual.2023.104995.

[29] M. Lim, S. Park, Y. Lee, and H. S. Kwak, "Brain responses and connectivity to visual meal compositions: an EEG investigation into food liking," *Food Quality and Preference*, vol. 112, 2023, doi: 10.1016/j.foodqual.2023.105029.

[30] I. Vermeir and G. Roose, "Visual design cues impacting food choice: a review and future research agenda," *Foods*, vol. 9, no. 10, 2020, doi: 10.3390/foods9101495.

[31] M. Vartanian *et al.*, "Neural responses to visual food cues according to weight and hunger state: a systematic review and meta-analysis," *Neuroscience and Biobehavioral Reviews*, vol. 177, 2025, doi: 10.1016/j.neubiorev.2025.106301.

[32] E. Schubert, D. Rosenblatt, D. Eliby, Y. Kashima, H. Hogendoorn, and S. Bode, "Decoding explicit and implicit representations of health and taste attributes of foods in the human brain," *Neuropsychologia*, vol. 162, 2021, doi: 10.1016/j.neuropsychologia.2021.108045.

[33] T. Yang *et al.*, "Insights into brain perceptions of the different taste qualities and hedonic valence of food via scalp electroencephalogram," *Food Research International*, vol. 173, 2023, doi: 10.1016/j.foodres.2023.113311.

[34] T. Yagyu *et al.*, "Chewing-gum flavor affects measures of global complexity of multichannel EEG," *Neuropsychobiology*, vol. 35, no. 1, pp. 46–50, 1997, doi: 10.1159/000119329.

[35] S. Maeda and H. Yoshimura, "Enhancement of electroencephalogram activity in the theta-band range during unmatched olfactory-taste stimulation," *Journal of Physiological Sciences*, vol. 69, no. 4, pp. 613–621, 2019, doi: 10.1007/s12576-019-00674-9.

[36] G. Forester, L. M. Schaefer, D. R. Dodd, and J. S. Johnson, "The potential application of event-related potentials to enhance research on reward processes in eating disorders," *International Journal of Eating Disorders*, vol. 55, no. 11, pp. 1484–1495, 2022, doi: 10.1002/eat.23821.

[37] E. Campos *et al.*, "Principle ERP reduction and analysis: estimating and using principle ERP waveforms underlying ERPs across tasks, subjects, and electrodes," *NeuroImage*, vol. 212, 2020, doi: 10.1016/j.neuroimage.2020.116630.

[38] A. Byrne, E. Bonfiglio, C. Rigby, and N. Edelstyn, "A systematic review of the prediction of consumer preference using EEG measures and machine-learning in neuromarketing research," *Brain Informatics*, vol. 9, no. 1, 2022, doi: 10.1186/s40708-022-00175-3.

[39] M. Domracheva and S. Kulikova, "EEG correlates of perceived food product similarity in a cross-modal taste-visual task," *Food Quality and Preference*, vol. 85, 2020, doi: 10.1016/j.foodqual.2020.103980.

[40] G. R. J. Christoffersen *et al.*, "Long-term visuo-gustatory appetitive and aversive conditioning potentiate human visual evoked potentials," *Frontiers in Human Neuroscience*, vol. 11, 2017, doi: 10.3389/fnhum.2017.00467.

[41] I. Wolz *et al.*, "Subjective craving and event-related brain response to olfactory and visual chocolate cues in binge-eating and healthy individuals," *Scientific Reports*, vol. 7, 2017, doi: 10.1038/srep41736.

[42] R. Janet *et al.*, "Cognitive and hormonal regulation of appetite for food presented in the olfactory and visual modalities," *NeuroImage*, vol. 230, 2021, doi: 10.1016/j.neuroimage.2021.117811.

[43] C. J. Lowe, W. R. Staines, F. Mannochio, and P. A. Hall, "The neurocognitive mechanisms underlying food cravings and snack food consumption. A combined continuous theta burst stimulation (cTBS) and EEG study," *NeuroImage*, vol. 177, pp. 45–58, 2018, doi: 10.1016/j.neuroimage.2018.05.013.

[44] Y. Jing, Z. Xu, Y. Pang, X. Liu, J. Zhao, and Y. Liu, "The neural correlates of food preference among music kinds," *Foods*, vol. 13, no. 7, 2024, doi: 10.3390/foods13071127.

[45] A. C. I. Rodriguez, M. S. Kirschner, and L. S. Nunes, "To stream or not to stream? watching TV while eating promotes increased calorie consumption, but using a smartphone does not," *Physiology and Behavior*, vol. 294, 2025, doi: 10.1016/j.physbeh.2025.114878.

[46] R. Jusienė *et al.*, "Screen use during meals among young children: exploration of associated variables," *Medicina*, vol. 55, no. 10, 2019, doi: 10.3390/medicina55100688.

[47] M. Peng, F. Liang, L. Yu, and H. Huang, "Smooth or rough? the impact of food packaging design on product healthiness perception," *Food Quality and Preference*, vol. 111, Oct. 2023, doi: 10.1016/j.foodqual.2023.104970.

[48] E. J. Szczygiel, S. Cho, and R. M. Tucker, "Characterization of the relationships between sleep duration, quality, architecture, and chemosensory function in nonobese females," *Chemical Senses*, vol. 43, no. 4, pp. 223–228, 2018, doi: 10.1093/chemse/bjy012.

[49] A. Krugliak and A. Clarke, "Towards real-world neuroscience using mobile EEG and augmented reality," *Scientific Reports*, vol. 12, no. 1, 2022, doi: 10.1038/s41598-022-06296-3.

[50] A. L. -Zhu, M. P. H. Lau, and G. McLoughlin, "Mobile EEG in research on neurodevelopmental disorders: opportunities and challenges," *Developmental Cognitive Neuroscience*, vol. 36, 2019, doi: 10.1016/j.dcn.2019.100635.

[51] A. Panteli, E. Kalaitzi, and C. A. Fidas, "A review on the use of EEG for the investigation of the factors that affect consumer's behavior," *Physiology and Behavior*, vol. 278, 2024, doi: 10.1016/j.physbeh.2024.114509.

[52] M. M. Ciobanu, E. I. Flocea, and P. C. Boișteanu, "The impact of artificial and natural additives in meat products on neurocognitive food perception: a narrative review," *Foods*, vol. 13, no. 23, 2024, doi: 10.3390/foods13233908.

[53] K. Colla, R. Keast, M. Mohebbi, C. G. Russell, and D. G. Liem, "Testing the validity of immersive eating environments against laboratory and real life settings," *Food Quality and Preference*, vol. 103, 2023, doi: 10.1016/j.foodqual.2022.104717.

[54] L. Yang, C. Zhang, W. Wu, J. Xie, and Z. Ding, "Advancements and applications of EEG in gustatory perception," *Brain Sciences*, vol. 15, no. 12, 2025, doi: 10.3390/brainsci15121317.

BIOGRAPHIES OF AUTHORS

Harish S. Sinai Velingkar holds a master's degree (M.Tech.) in Communication Systems from R.V. College of Engineering, Bengaluru, affiliated with Visvesvaraya Technological University, Belagavi, Karnataka, India, completed in 2014. He received his bachelor's degree in Electronics and Telecommunications from Padre Conceicao College of Engineering, Verna, affiliated with Goa University, Goa, India, in 2012. He is currently serving as an assistant professor in the Department of Electronics and Communication Engineering at Agnel Institute of Technology and Design (AITD), Visvesvaraya Technological University, Goa. He has over 12 years of teaching experience. His areas of interest include biomedical engineering, cognitive neuroscience, brain computer interface (BCI), embedded systems, image processing, computer networks, cryptography, and network security. He is currently pursuing his Ph.D. Dayananda Sagar Academy of Technology and Management (DSATM), Bengaluru, India affiliated with Visvesvaraya Technological University, Belagavi, Karnataka, India in cognitive neuroscience with a focus on sensory processing and neural correlates of perception. He can be contacted at email: harishvelingkar@gmail.com.

Dr. Roopa R. Kulkarni received her Ph.D. in Low Power VLSI from Visvesvaraya Technological University, Belagavi, in 2019. She completed her M.Tech. in VLSI Design and Embedded Systems from the same university in 2005. She is currently working as an associate professor in the Department of Electronics and Communication Engineering at Dayananda Sagar Academy of Technology and Management (DSATM), Bengaluru, India. With over 26 years of teaching experience, her areas of interest include low power VLSI design and verification, internet of things (IoT), artificial intelligence, and embedded system design. She is a senior member of IEEE and a life member of ISTE. She has contributed to various research publications in reputed journals and conferences and is actively involved in academic mentoring. She can be contacted at email: roopakulkarni-ece@dsatm.edu.in or roopa.patavardhan@gmail.com.

Dr. Prashant Patavardhan received his B.E. in Electronics and Communication Engineering from Karnataka University in 1995. He earned his M.Tech. in Digital Electronics and Communication Systems from Visvesvaraya Technological University (VTU), Belagavi, in 2001, graduating as the University Topper. He was awarded the Ph.D. degree by VTU, Belagavi in 2011. With over 28 years of academic experience, He has served in various teaching, research and academic leadership roles. He has held the position of professor and head at reputed institutions, including in Department of Electronics and Communication Engineering, RV Institute of Technology and Management (RVITM), Bengaluru, Dayananda Sagar University, Bengaluru and KLS Gogte Institute of Technology (KLS GIT), Belagavi. Throughout his career, he has made significant contributions to academic administration, curriculum development, outcome-based education, research supervision and institutional quality enhancement. His research interests include biometrics, signal, image and video processing, artificial neural networks, fuzzy logic, pattern recognition, embedded systems and intelligent computing. He has published more than 27 research articles in international journals and has presented his research at several national and international conferences. He can be contacted at email: prashantgemini73@gmail.com.

Dr. Abdul Haq Nalband received his B.E. degree from Visvesvaraya Technological University, Belagavi, in 2010, and his M.Tech. Degree in Communication Systems from Visvesvaraya Technological University, India, in 2014. He is currently working as associate professor in Department of Computer Science and Engineering (AI and ML), Dayananda Sagar University, Ramanagara, Bengaluru, Karnataka, India. He did Ph.D. in 5G Technologies in 2022. He recently completed the visiting postdoctoral fellowship in Cyber Security from City, University of London, United Kingdom. He has published more than 20 research articles in indexed journals and conference. He has published 3 patents, out of which one international patent is granted for his innovation. He is a Member of the IEEE, USA, a life member of the Indian Society for Technical Education (ISTE, India), and associate member of IETE, India. He has funded projects to his credit in the areas of wireless and mobile communication, currently he is working on a project 'Protocols for reconfigurable communication system on ultra-massive MIMO architecture', funded by ISRO. His student projects explore the areas of 5G and beyond, blockchain, web 3.0, artificial intelligence, and IoT security. He can be contacted at email: abjag.n@gmail.com.