

## RESEARCH ARTICLE OPEN ACCESS

# How Flavorsome Was That Movie? Using a Bayesian Network Approach to Understand How Audiovisual Stimuli Influence Emotions and Flavor Perception

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## ABSTRACT

This study utilized the temporal check-all-that-apply (TCATA) approach to investigate the impact of viewing video clips on the perception of ice cream. The association between subjectively rated emotions and their electrophysiological correlates was further explored using Bayesian network (BN) modelling. Participants consumed chocolate ice cream under different video conditions, and sweetness, bitterness, milkiness, creaminess, cocoa flavor, and roasted flavor ratings were acquired using the TCATA approach. Additionally, electrophysiological measurements of heart rate (HR), skin conductance (SC), and blood volume pulse (BVP) amplitude were obtained. The results showed that videos that evoked pleasant emotions, such as enjoyment and relaxation, were associated with increased ratings of sweetness and creaminess. Conversely, videos that evoked negative feelings, such as stress, were linked to higher ratings of bitterness. Furthermore, changes in electrophysiological measures were consistent with the variety of affective states evoked by the videos. Arousing videos increased HR and SC, while videos that induced calmness had the opposite effect. The use of BN modelling revealed significant relationships between affective states and electrophysiological responses with flavor perception. The model demonstrated that HR and SC were positively correlated with positive emotions that contributed to the perception of sweetness and milkiness, respectively. On the other hand, BVP amplitude was negatively correlated with arousal and perceptions of cocoa. Additionally, ratings of 'quiet' and 'excited' emotions were positively correlated to creaminess, while tension was positively correlated to roasted flavor. These findings indicate that understanding the impact of emotions on food perception can facilitate the design of consumer experiences that enhance enjoyment and engagement with food products.

## 1 | Introduction

Stimuli in our environments elicit emotional responses known as affective states, which can be understood through the three dimensional PAD (pleasure-arousal-dominance) model (Mehrabian and Russell 1974). The emotional responses evoked

by videos can vary greatly as they combine multiple elements, such as visual, audio, storytelling, and music. In a study by Muszynski et al. (2019), it was found that action movies generally elicited higher levels of arousal and pleasure compared to other genres. The literature has established the influence that videos have on our emotional responses,

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and how factors like music can moderate these responses (Ma 2022).

The impact of videos on food perception is a novel area of study, where a video consists of moving visual images, typically accompanied by sound that can be played back on screens or devices. Only James et al. (2022) have conducted research on the impact of various types of food-related videos on flavor perception, including the emerging 'mukbang' genre, an online audiovisual broadcast where the host consumes various food types while interacting with the audience. Their findings revealed that different food-related videos evoked positive emotional states and influenced participants' flavor perceptions of white rice, including spiciness and saltiness. Kong et al. (2020) demonstrated that chocolate presented in pleasant virtual reality (VR) settings received higher liking scores and elicited more positive emotional responses compared to unpleasant VR settings, emphasizing the impact of immersive environments on flavor perception. Moreover, Song et al. (2022) discovered that older consumers (aged between 60 and 80 years) showed a preference for protein-enriched rye bread in VR restaurant settings over VR movie settings, underscoring the importance of selecting appropriate contexts for consumer experiences. However, while audiovisual stimuli have been shown to influence food perception, more studies are needed to understand the underlying mechanisms.

Emotions are complex subjective phenomena characterized by both somatic responses and cognitive interpretations, and whose multidimensional nature serves an adaptive function. External stimuli can have a significant impact on physiological, cognitive, and behavioral processes, and the diverse ways in which audiovisual stimuli can impact felt emotion, perception, and electrophysiological responses are in the process of being documented. For example, Wang et al. (2020) explored the physiological effects of viewing videos depicting bamboo forest environments in China, noting a significant decrease in blood pressure. In another study, Wöllner et al. (2018) investigated the effects of slow-motion (SloMo) and real-time audiovisual media on time perception, emotional states, and electrophysiological measures. Their study demonstrated that visual stimuli accompanied by music amplified physiological responses across both the SloMo and real-time conditions, with significant increases in skin conductance, heart rate, and pupil dilation. Additionally, the inclusion of music influenced affective responses, with higher levels of arousal and pleasantness reported in the presence of background music.

Temporal sensory methods are commonly used to profile the sensory dynamics of food products, with each method offering unique advantages depending on research objectives. For example, the time-intensity (TI) approach tracks the intensity of a single sensory attribute over time, making it ideal for specific sensory dimensions but potentially time-consuming for complex products (Cliff and Heymann 1993; Boinbaser et al. 2015; He et al. 2021). Multiple time-intensity (MTI) methods extend the TI approach by permitting multiple sensory attributes to be judged simultaneously, though it requires trained panelists and careful protocol design (Castura et al. 2016; Morais et al. 2014). The temporal dominance of sensations (TDS) procedure documents the sequence of dominant sensations and has proved easy to implement and suitable for consumer studies (Di Monaco et al.

2014; Galmarini et al. 2017; He et al. 2021). However, it is the temporal check-all-that-apply (TCATA) method that offers the most comprehensive approach, allowing the continuous selection or de-selection of all applicable attributes, allowing the derivation of detailed multi-attribute temporal profiles (Boinbaser et al. 2015; Castura et al. 2016; Kantono et al. 2018; Lin et al. 2019). The TCATA method enables assessors to consider multiple attributes simultaneously, endowing it with an advantage over other techniques given that flavors are seldom experienced in complete isolation. The TCATA method, however, may require additional guidance for untrained panelists. To address this, panelist training and methodological modifications, such as incorporating a 'fade time' for attribute selection, can improve both accessibility and accuracy (Esmerino et al. 2017). Ultimately, the choice of temporal sensory methods depends on the specific research objectives, product complexity, and available resources, with each approach providing unique insights into the dynamic sensory experience of food products.

The TCATA method has been used to investigate the changes in flavor perception using different sound stimuli. Research conducted by Lin et al. (2019) revealed that cafe and park soundscapes were mainly associated with high valence and further correlated with enhanced perceptions of sweet and creamy in chocolate ice cream. On the other hand, bar, fast food restaurant, and food court sounds were associated with high arousal ratings and were correlated to enhanced perceptions of roasted, cocoa, and bitter. In another study (Kantono et al. 2018), participants listened to liked, neutral, and disliked music while evaluating sensory perception of chocolate ice cream using the TCATA method. Correspondence analysis (CA) results indicated that listening to disliked music was associated with creaminess and bitterness. In addition, listening to liked music was associated with sweetness, while neutral music was associated with milky and cocoa attributes when consuming chocolate ice cream. Moreover, Lin et al. (2022) reported that chocolate milkshake sample consumed under pleasant soundcondition was associated with sweet taste. These studies demonstrate that TCATA is a valuable method for investigating the complex interactions between auditory stimuli and dynamic flavor perception, revealing how different soundscapes and music preferences can significantly influence the temporal sensory experience of food products.

The Bayesian network (BN) approach is a relatively new statistical framework that employs a directed acyclic graph (DAG) to delineate a set of variables and their conditional dependencies. Utilizing DAGs to encode domain knowledge and perform inference on complex datasets, BN models have gained prominence in various fields such as artificial intelligence, bioinformatics, and machine learning due to their ability to integrate heterogeneous data (Jensen 1996; Korb and Nicholson 2010; Murphy 2002). In the food industry, the BN approach has been applied to predict grape berry quality, model the cheese ripening processes, and detect vulnerabilities in food supply chains (Baudrit et al. 2010; Bouzemrak et al. 2024; Perrot et al. 2022). More recently, BN models have found application in the sensory sciences. Phan et al. (2011) used BN to understand how food labelling affects product perception, demonstrating the network's ability to represent intricate consumer responses. Additionally, Phan et al. (2012) further used BN to examine combined raw datasets from two independently performed but related studies on sensory satiation

by measuring the unrestricted intake of tomato soup, demonstrating how BN can provide insights into complex relationships between perception and satiation.

Studies have shown that sounds and immersive environments can influence felt emotions and electrophysiological responses that, in turn, influence flavor perception. Kantono et al. (2019) demonstrated that consuming chocolate ice cream while listening to liked music led to increased heart rate, ratings of positive emotions, and perceptions of sweetness and milkiness, whereas disliked music resulted in higher skin conductance levels, as well as increased negative emotions, and perceptions of bitterness and creaminess. Similarly, Xu et al. (2019a) found that a café soundscapes overlaid with machine sounds induced negative reactions and increased physiological arousal, which were further positively correlated with perceptions of creamy and bitter attributes, while café-forest sounds evoked positive emotions and enhanced sweetness perception.

Currently, there is a significant gap in the multisensory literature in the understanding of how emotive videos affect flavor perception. Using BN, an effective tool for investigating complex relationships across domains, this study aims to explore how videos evoking different emotions can influence electrophysiological responses and the temporal changes in flavor perception of chocolate ice cream. By examining the emotional and physiological states evoked by these videos, this research addresses the current knowledge gap regarding the impact of video-induced emotions on flavor perception. The novelty of this study lies in leveraging BN modelling to explore the intricate relationships between video-induced emotions, electrophysiological measures, and how they link to flavor perception.

## 2 | Material and Methods

### 2.1 | Ethics Statement

This work received ethical approval from the Auckland University of Technology Ethics Committee (AUTEC: 17/202). Participants provided informed consent prior to the study and were rewarded with supermarket coupons following its completion.

### 2.2 | Participants

Participants were solicited online through advertisements placed on social networking platforms such as Facebook (Cambridge, MA, Meta Platforms, Inc.) and Instagram (San Francisco, Meta Platforms). All participants were non-smokers and had no documented instances of hearing loss or allergies to chocolate ice cream. A total of 77 individuals, consisting of 35 males and 42 females, between the ages of 20 and 40 were selected (mean age = 35.09 years; SD = 8.64 years) for the study. The sample size was selected based on a Cohen's *d* value of 0.8, resulting in a statistical power of 0.90–0.95 (Kenny 1987).

### 2.3 | Ice Cream Preparation and Presentation

The formulation of the bitter-sweet chocolate ice cream samples consisted of a blend of cream (51.54%), milk (15.38%), sugar (15.38%), and cocoa powder (7.69%), as used in other studies

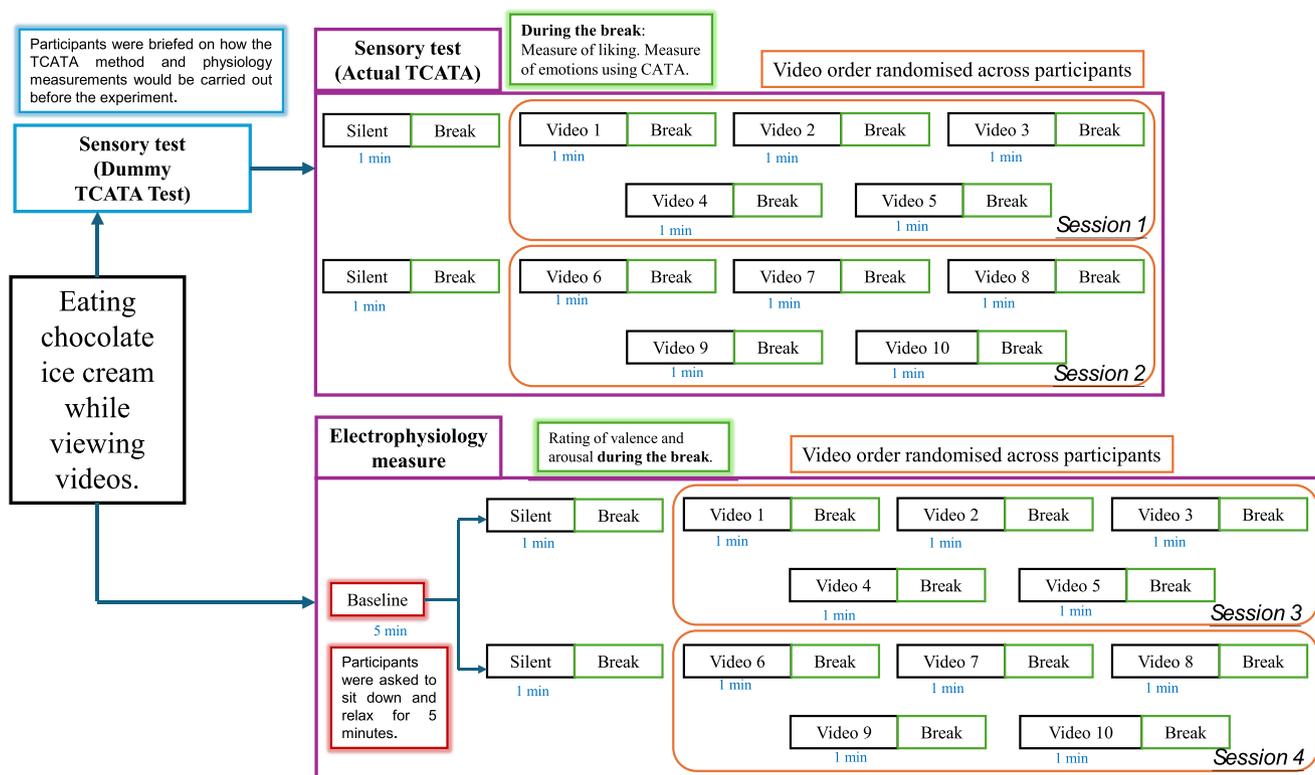
(Kantono et al., 2016a, 2016b, 2016c, Kantono et al. 2018, Kantono et al. 2019; Lin et al. 2019, 2022a, 2022b; Xu et al. 2019a, 2019b). The ingredients were added to an ice-cream maker (Cuisinart ICE-100 Compressor Ice Cream and Gelato Maker, Stamford, USA, Cuisinart) and agitated until the mixture achieved a thick consistency. Subsequently, the samples were placed in 250-mL polystyrene cups and stored in a freezer (Fisher & Paykel, New Zealand) at a temperature of  $-18^{\circ}\text{C}$  for a minimum of 24 h to ensure uniformity of the samples before being served. Prior to serving, all ice cream samples were brought to room temperature by tempering them for 1 min. An individual portion of the ice cream sample, weighing  $5.0 \pm 0.8$  g, was placed in a sealed 15 mL white plastic container with a diameter of 45 mm. The container was labelled with a three-digit random number to prevent carry-over effects that could be caused by participants knowing that the samples were all the same. To preserve consistency, the temperature at which the samples were served ( $-12 \pm 2^{\circ}\text{C}$ ) was carefully controlled to ensure that all participants received samples at the same temperature. The participants were provided with a 30-s interval between samples during which they were instructed to consume water to cleanse their palate.

## 2.4 | Experimental Procedure

The experimental design used in this study is outlined in Figure 1, with all data collected in a purpose built sensory laboratory. During a pre-test session, participants provided affective ratings to 10 video clips, with a 1-min break between each video. Participants were then requested to attend the laboratory on four further occasions to consume chocolate ice cream while viewing videos. In the first and second experimental sessions, participants consumed chocolate ice cream while watching the videos and assessed the sensory properties of the ice cream using the TCATA method. Participants were then required to provide a hedonic judgment of the chocolate ice cream (i.e., liking) and to indicate their emotional state using the check-all-that-apply (CATA) method from a list of 12 emotions derived from the circumplex-inspired emotion questionnaire (CEQ). The CEQ, developed by Jaeger et al. (2020), uses a range of terms to encompass the breadth of the human emotional experiences based on the circumplex model of affect, categorized by their position on the valence (pleasant-unpleasant) and arousal (high-low energy) dimensions. In the third and fourth experimental sessions, electrophysiological measures were collected during a 10-min rest period in which no ice cream was consumed, and no videos were viewed. Following the rest period, participants then watched the videos and consumed ice cream, and their affective responses and electrophysiological activity were again recorded.

## 2.5 | Rating of Video-Evoked Emotions

In a preliminary study, a total of 615 participants (302 males and 313 females) between the ages of 20 and 60 years (mean age = 35.27 years, SD = 8.79 years) responded to an online Qualtrics survey which featured 39 different videos (Appendix 1). Participants viewed the videos and reported their emotional states using the CATA method, selecting from a list of 12 emotions after viewing each video for 1 min. A correspondence analysis (Appendix 2) revealed significant differences in the emotions evoked across the different videos.



**FIGURE 1** | The experimental protocol carried out in this study.

A total of 10 videos (Table 1) were finally chosen for the actual experiment based on the patterns of emotional responses evoked, each with a duration of 60 s. An additional correspondence analysis (Appendix 3) was performed to elucidate the differences in emotional responses across the 10 videos (denoted V). Specifically, the V1 and V2 (action) videos showed a strong correlation with feelings of being nervous and tense, while the V3 (animation and adventure) video was associated with feelings of happiness and enthusiasm. The V7 and V8 (classical crossover) videos were found to evoke emotions of action, excitement, and enthusiasm, while V4 (scenic relaxation) and V5 (nature documentary) were associated with a sense of calmness. Finally, V9 (nature documentary) and V10 (scenic relaxation) were highly correlated with feelings of being at ease and relaxed, and V6 (nature documentary) exhibited a strong correlation with happiness.

Immediately after viewing each of the 10 videos, the participants ( $n = 77$ ) selected emotions from a list of 12 options using the CATA method. Each participant watched the videos on a personal computer (PC) located in a laboratory, with audio delivered through a pair of Sennheiser Series HD 518 headphones (Sennheiser Electronics GmbH and Co. KG, Wademmark, Germany). Video editing was done using Adobe Premiere Pro 2.0, and the audio was standardized by using Adobe Audition 3.0 to equalize the root mean square amplitude across the videos.

## 2.6 | Temporal Check-All-That-Apply Method

The impact of viewing different videos on the flavor perception of chocolate ice cream was documented in the first and second

experimental sessions using the TCATA method, as described by Castura et al. (2016). This method involves the selection and deselection of flavor characteristics that enables participants to report the perceptual changes of the ice cream over time. The TCATA procedure employed in this investigation was modified from Boinbaser et al. (2015) by utilizing onscreen radio buttons representing the flavor attributes (e.g., Kantono et al. 2018; Lin et al. 2019). The TCATA data were encoded across time using binary values, where 0 represented unchecked attributes and 1 represented checked attributes. Throughout the session, the participants monitored the flavor attributes of the ice cream sample by checking them when relevant and unchecking them when not relevant.

The study sought to investigate the dominant flavor characteristics of the ice cream, which included sweetness, bitterness, cocoa flavor, creaminess, milkiness, and roasted flavor. Appendix 4 provides the description and reference standards of the seven flavor attributes (Kantono et al. 2018, 2019; Y. H. T. Lin et al. 2019, 2022b; Xu et al. 2019a, 2019b). Each TCATA session lasted for the duration of the video (i.e., 60 s), and participants were subjected to a compulsory 60-s period of silence between each video.

### 2.6.1 | Panel Familiarization and Evaluation of Samples Using TCATA

Prior to participating in the first and second experimental sessions, participants were provided an overview of the TCATA approach. The six attributes listed in Appendix 4 were displayed on monitors using the FIZZ sensory data acquisition software

**TABLE 1** | Videos (V) used in the current study.

Code	Video/link	Genres	Description
V1	Without remorse <a href="https://www.youtube.com/watch?v=e-rw2cxFVLg&amp;t=12s">https://www.youtube.com/watch?v=e-rw2cxFVLg&amp;t=12s</a>	Action, thriller and military	Features intense combat scenes, explosions, and high-stakes missions.
V2	Shadow in the cloud <a href="https://www.youtube.com/watch?v=XjLnk8YriCQ">https://www.youtube.com/watch?v=XjLnk8YriCQ</a>	Action, horror and war genres	Features intense aerial combat scenes and high-stakes action sequences set during World War II.
V3	Space jam: A new legacy <a href="https://www.youtube.com/watch?v=olXYZOsXw_ov">https://www.youtube.com/watch?v=olXYZOsXw_ov</a>	A blend of animation, adventure, comedy, family, and science fiction	Features basketball superstar LeBron James and his son Dom getting trapped in a digital world by a rogue A.I.
V4	4K Winter waterfall scene – Probiy Waterfall, the Carpathians, Ukraine—Trailer 49 <a href="https://www.youtube.com/watch?v=x8tvYjRxXno&amp;t=31s">https://www.youtube.com/watch?v=x8tvYjRxXno&amp;t=31s</a>	Scenic relaxation	Showcases a winter waterfall in the Carpathians, accompanied by water sounds.
V5	Planet ocean <a href="https://www.youtube.com/watch?v=etExgF52XlQ">https://www.youtube.com/watch?v=etExgF52XlQ</a>	Nature documentary	Providing insights into the behaviors and interactions of various sea creatures and the importance of oceans to life on Earth.
V6	Secrets of the sea <a href="https://www.youtube.com/watch?v=zY4cdXlQaBA">https://www.youtube.com/watch?v=zY4cdXlQaBA</a>	Nature documentary	Showcases visuals of marine life and underwater ecosystems with narration.
V7	2CELLOS—Pirates Of Caribbean [OFFICIAL VIDEO] <a href="https://www.youtube.com/watch?v=Xj3gU3jACe8">https://www.youtube.com/watch?v=Xj3gU3jACe8</a>	Classical crossover	This piece is a modern interpretation of a well-known film score, blending classical instrumentation with a contemporary, rock-inspired performance.
V8	Vanessa-Mae—Storm (official video) <a href="https://www.youtube.com/watch?v=mdFrn89x74k">https://www.youtube.com/watch?v=mdFrn89x74k</a>	Classical crossover	This piece is a modern interpretation of Vivaldi's 'Storm' from The Four Seasons, combining classical composition with contemporary production techniques.
V9	One hour of amazing ocean moments   BBC Earth <a href="https://www.youtube.com/watch?v=CSgDjZ_Vv8g">https://www.youtube.com/watch?v=CSgDjZ_Vv8g</a>	Nature documentary	Showcases breath-taking visuals of ocean life, including underwater hunts and dancing whales with narration.
V10	Patagonia 4K—Scenic relaxation film with calming music <a href="https://www.youtube.com/watch?v=DsXMR7dY35w">https://www.youtube.com/watch?v=DsXMR7dY35w</a>	Scenic relaxation	Features stunning visuals of Patagonia's landscapes accompanied by calming music.

(FIZZ Network v2.46b, Biosystemes). The attributes appeared in a column on the screen, and the order remained consistent for each participant during the product evaluations (Meyners and Castura 2016). Before the actual trials, participants familiarized themselves with the TCATA technique by practicing with chocolate ice cream. The ice cream was served in individual portions weighing  $5.00 \pm 0.80$  g and placed in a 25-mL plastic cup with a unique three-digit random number label. When participants took the first scoop of ice cream in their mouth ( $t = 0$  s), they pressed the start button and began selecting or deselecting the sensory attributes on the screen. Participants were instructed to swallow the sample at the 20-s mark and continued selecting the relevant attribute until the conclusion of the 60-s period.

Following the familiarization session, participants assessed chocolate ice cream ( $-12 \pm 2^\circ\text{C}$ ) under various video conditions during a 2-h practice session using the TCATA method. Before the actual trial, participants were provided with a practice sample to mitigate any potential initial biases. Participants were given a mandatory 5-min rest between each condition and instructed to cleanse their palate with filtered water to minimize any lingering flavor. The ice cream assessments were carried out in sensory booths at a temperature of  $21 \pm 1^\circ\text{C}$ , illuminated by white light. Prior to commencing the product assessments, participants were given the attribute definitions shown in Appendix 4 and provided opportunities to ask questions or seek further clarification regarding the attribute definitions.

## 2.6.2 | Emotional Responses to Ice Cream Consumption

The study collected the affective responses of participants immediately following the consumption of ice cream and the viewing of a video, during the first and second experimental sessions. An unstructured line scale of 40 cm was presented on a monitor and used to assess pleasantness (ranging from unpleasant to pleasant) and arousal (ranging from excited to calm).

The CATA technique was used to gather self-report emotion ratings (Ares et al., 2017; Gunaratne et al., 2019; Meyners and Castura 2016; Meyners et al. 2013), comprising a list of 12 emotions (Appendix 5) selected from the CEQ (Jaeger et al. 2020). Participants were instructed to tick all relevant emotion terms from the list after consuming the chocolate ice cream and viewing a video. The presentation order of the CATA terms was counterbalanced both between and within participants, following a Williams' Latin square experimental design. Participants used the Fizz software to select the appropriate emotion.

## 2.7 | Electrophysiological Measurement of Emotion

In the third and fourth experimental sessions, a NeXus 10 MK-II multimodal signal acquisition device was used to obtain electrophysiological measures of skin conductance (SC), heart rate (HR) as derived from the electrocardiogram (ECG), and blood volume pressure (BVP) amplitude, all recorded at a sampling rate of 128 samples per second. The data were processed using the BioTrace+ software (V2018A) developed by Mind Media BV (Van der Zwaag et al. 2011).

Pre-gelled silver–silver chloride (Ag–AgCl) electrodes were used for the SC and ECG sensors. Prior to attaching the electrodes, the skin area was exfoliated and cleansed using isopropyl alcohol. The measurement of SC involved the placement of an electrode on the volar surface of the medial phalanges on the middle and ring fingers. BVP, representing relative blood flow, was measured by attaching a clip to the pointer finger. The ECG was acquired using a traditional three-lead configuration (i.e., standard lead II placement), with HR estimated from the time intervals between consecutive heartbeats.

The electrophysiological measurements commenced with a 5-min baseline period, during which participants were instructed to assume an upright and comfortable posture while seated. Participants were specifically instructed to keep their non-dominant hand stationary throughout the experiment. During the third and fourth experimental sessions, participants were seated in front of a monitor and received a headset (Series HD 518, Sennheiser Electronics GmbH and Co. KG) and were instructed to view the videos while electrophysiological measures were obtained. Next, participants consumed chocolate ice cream ( $7.0 \pm 0.5$  g) either in a quiet environment or while viewing videos, allowing for a comparison of how environmental factors influence their experience.

## 2.8 | Data Analysis

The data analysis involved examining the changes in (1) the perception of the ice cream using TCATA; (2) self-reported emotions using CATA; and (3) electrophysiological responses, obtained while participants viewed different videos.

### 2.8.1 | Temporal Measures of Flavor Perception

**2.8.1.1 | Temporal Check-All-That-Apply Curves.** TCATA curves were produced using the FIZZ software. These curves represent the percentage of participants who identified a particular flavor characteristic at a specific point in time. A higher citation rate for an attribute reflects a greater consensus among the participants regarding the frequency of that attribute. Each curve was smoothed using a spline-based method to enhance the visualization of the TCATA curves (Lenfant et al. 2009).

The TCATA curves were analyzed following the methodology described by Castura et al. (2016). Citation proportions were determined by calculating the percentage of participants who selected an attribute at a specific moment during the evaluation period. In this study, the TCATA time was represented as standardized time (ST) to enhance comprehension and emphasize agreement amongst the participants. Each participant's time data were normalized on a scale ranging from 1 to 100, with 0 representing the initial click on the line scale and 100 indicating when the recording automatically ended.

**2.8.1.2 | Correspondence Analysis.** CA was performed using XLSTAT V.2024 (Lumivero, Denver, USA) to visually represent the total durations of specific perceptual attributes in the TCATA data. The cumulative duration of attributes was calculated by summing the total CATA counts of each attribute for each product across all participants, as a function of time. CA was applied to depict the temporal evolution of perceptual attributes along a simplified path, providing a visual representation that facilitates the understanding and analysis of product characteristics over time (Castura et al. 2016). Furthermore, chi-square tests of independence were conducted to investigate the association between perceptual attributes and the 10 videos.

### 2.8.2 | Measurement of Emotions Using CATA

**2.8.2.1 | Multidimensional Alignment.** Multidimensional alignment (MDA) was performed using the XLSTAT V.2024 (Lumivero, Denver, USA), to analyze the CATA results (Carr et al. 2009; Meyners et al. 2013). This involved calculating the cosine values between the 10 videos and the emotion attributes obtained from the CA performed on the CATA questions. The degree of association between each attribute and condition was determined by measuring the cosine of the angle, which ranged from  $-1$  to  $1$ . Cosines with an absolute value below  $0.707$  indicate a relationship that can be considered negligible (Carr et al. 2009).

### 2.8.3 | Electrophysiological Responses

Average change values of the electrophysiological parameters, including SC, HR, and BVP amplitude, were calculated across time intervals of interest. The 10-min baseline period was used as the reference, with percentage change from baseline calculated according to Equation (1) (H. P. Lin et al. 2011; Miller and Ditto 1989).

$$\text{Percentage change (\%)} = \frac{(\text{each value during testing} - \text{each value during baseline})}{\text{each value during baseline}} \times 100\%. \quad (1)$$

An one-way analysis of variance (ANOVA) was performed on the transformed electrophysiological data using XLSTAT, with video as the main factor. Tukey post hoc comparisons were performed when statistical significance was achieved.

**2.8.3.1 | Multiple Factor Analysis.** Multiple factor analysis (MFA) is used to analyze and visualize relationships between multiple sets of variables, typically by extending principal component analysis to datasets structured by groups of variables (Escofier and Pagès 1984). In this study, MFA was applied to the TCATA data, as well as the self-report emotion ratings obtained using CATA and the electrophysiological measures, across all video samples. This allowed the relationship between the ice cream ratings, electrophysiological measures, and emotional measurements to be explored as a function of video.

### 2.9 | Bayesian Network

A BN model using the pgmpy (Pgmpy 0.1.23 Documentation, 2023) and NetworkX (NetworkX Documentation, 2014) packages in Python (ver. 3.12.5, Python Software Foundation (PSF), Delaware, USA) (Ankan and Panda 2015; Arulkumar et al. 2022; Hagberg et al. 2008) was employed to undertake a network analysis. The BN model structure was determined using a heuristic score-based Hill Climbing algorithm, as outlined by Cosic (2021), and optimized using the Bayesian information criterion (BIC) score, following the methodology described by Nagarajan et al. (2013). This algorithm was selected for its ability to iteratively adjust the BN by adding, removing, or reversing edges to enhance the model's quality until no further improvements could be achieved, thereby ensuring an optimal and robust model structure. This approach allows the detection of subtle changes in the data while maintaining robustness (Nagarajan et al. 2013; Threlfal 2022).

The BIC score, a widely accepted metric for assessing the goodness of fit of BN models, was employed to evaluate the network's performance. The BN model in this study was optimized after 44 iterations using the Hill Climbing algorithm, with the constructed BN model providing a visual representation of the probabilistic relationships among variables, facilitating the integration of domain knowledge into the model development process. The nodes in the BN represent different variables, and the directed

edges denote the conditional dependencies (i.e., associations) between these variables. This graphical representation aids in understanding the complex relationships within the data and enhances the model's interpretability without extensive machine learning expertise (Nagarajan et al. 2013; Threlfal 2022).

## 3 | Results

### 3.1 | The Emotions Evoked Under Different Video Conditions

#### 3.1.1 | Emotions Elicited After Consuming Chocolate Ice Cream Under Different Video Conditions

MDA was applied to determine the cosine values between the 10 videos and the cited emotions when consuming chocolate ice cream. The MDA results, presented in Table 2, show the positive or negative correlations between emotions and ice cream consumption across the different videos. A cosine value of  $>0.707$  suggests a strong relationship between a video and the emotions it evoked (Carr et al. 2009).

The findings indicate associations between specific video content and emotional response. Consuming chocolate ice cream during a silent condition was found to be positively correlated with feelings of being active, enthusiastic, and at ease. Action movie trailer videos (V1 and V2) were linked to emotions of nervousness and tension, while the classical crossover music video (V8) was associated with feelings of arousal, unhappiness, and tension. The animation, adventure, and comedy video (V3) only showed a positive correlation with arousal. Moreover, the scenic relaxation videos (V4 and V10), as well as nature documentary videos (V5, V6, and V9), exhibited positive correlations with emotions such as relaxation, quietness, boredom, and pleasantness.

### 3.2 | Temporal Check-All-That-Apply

Figure 2 depicts the overall TCATA curves for chocolate ice cream consumed during silence or while viewing one of the 10 videos. The augmented reference lines indicate the citation proportions that were statistically significant and not selected by chance, and only attributes that reached significance will be discussed here. It was found that for V8, sweetness, milkiness, creaminess, and roasted were the most frequently cited attributes. Similarly, for V9, milkiness and cocoa notes were the most cited attributes.

#### 3.2.1 | Sweet

In the nature documentary (V9), scenic relaxation (V10), and classical crossover music (V7) videos, sweetness was highly cited, ranging from 73% to 100% standardized time (ST), 84% to 100%

**TABLE 2** | Cosine values, obtained with correspondence analysis, between video conditions and the terms used to describe the emotions.

	Silent	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
Active	0.873	-0.117	-0.095	-0.197	-0.827	-0.968	-0.948	-0.213	-0.329	-0.963	-0.984
Excited	0.209	0.562	0.578	0.528	-0.533	-0.688	-0.532	0.474	0.386	-0.723	-0.728
Enthusiastic	0.736	-0.243	-0.235	-0.103	-0.706	-0.808	-0.785	0.186	-0.083	-0.771	-0.821
Happy	-0.254	-0.280	-0.274	0.483	0.168	0.285	0.434	0.536	0.209	0.465	0.362
At ease	0.745	-0.739	-0.739	-0.891	-0.350	-0.274	-0.458	-0.853	-0.911	-0.239	-0.252
Relaxed	-0.690	-0.168	-0.190	0.018	0.759	0.943	0.928	0.030	0.065	0.968	0.972
Quiet	-0.865	0.102	0.080	0.182	0.846	0.990	0.946	0.166	0.289	0.953	0.990
Bored	-0.809	0.230	0.221	0.375	0.976	0.768	0.772	0.269	0.453	0.579	0.712
Uninspired	-0.894	0.248	0.266	0.477	0.875	0.800	0.799	0.385	0.650	0.761	0.798
Unhappy	-0.428	0.723	0.666	0.349	0.174	0.051	0.040	0.448	0.747	-0.075	-0.026
Tense	-0.538	0.983	0.993	0.613	0.045	-0.016	0.105	0.464	0.769	-0.043	-0.030
Nervous	-0.470	0.992	0.985	0.458	0.017	-0.046	0.045	0.330	0.625	-0.098	-0.068
Valence	-0.760	0.201	0.170	-0.071	0.760	0.902	0.774	-0.147	0.151	0.829	0.883
Arousal	-0.925	0.651	0.641	0.736	0.552	0.605	0.750	0.680	0.769	0.599	0.608

Note: Values highlighted in green and orange indicate high positive and negative associations, respectively, for the emotion terms obtained when ice cream samples were consumed under different video conditions.

ST, and 76% to 100% ST, with citation rates between 68.83% and 74.03%, 63.64% and 64.94%, and 63.64% and 67.53%, respectively.

### 3.2.2 | Bitter

In the classical crossover music video (V8), bitterness was increasingly cited, starting from 2% to 19% ST, reaching a maximum citation rate of 54.55% at 19% ST. Subsequently, bitterness was consistently cited from 19% to 100% ST, with citation rates ranging between 54.55% and 63.64%. Moreover, under the silent condition, bitterness was highly cited from 21% to 64% ST and 73% to 89% ST, with citation rates between 40.43% and 46.1%, and 46.1% and 48.94%, respectively.

### 3.2.3 | Milky

In the animation and adventure video (V3), milkiness was increasingly cited, ranging from 18% to 40% ST, reaching a maximum citation rate of 60.49% at 40% ST. Subsequently, milkiness was steadily cited from 40% to 72% ST, with citation rates between 51.56% and 60.49%.

In the scenic relaxation (V4) and nature documentary (V5) videos, milkiness was increasingly cited from 18% to 58% and 11% to 53% ST, respectively. For these videos, milkiness reached a maximum citation rate of 57.81% at 58% ST and 53% ST. Following this, milkiness was steadily cited from 58% to 65% and 53% to 100% ST for V4 and V5, with citation rates ranging from 54.69% to 57.81% and 51.56% to 57.81%, respectively.

For the nature documentary video (V6), milkiness was increasingly cited from 0% to 10% ST, and 43% to 55% ST, reaching maximum citation rates of 46.88 and 64.06%, respectively. From

55% to 100% ST, the citation rates of milkiness attribute decreased from 64.06% to 48.44%.

### 3.2.4 | Creamy

In the animation and adventure (V3), scenic relaxation (V4), and nature documentary (V5) videos, creaminess was increasingly cited from 3% to 48% ST, 0% to 51% ST, and 0% to 58% ST, reaching maximum citation rates of 71.88%, 71.88%, and 67.19%, respectively. Then, from 48% to 100% ST, 51% to 87% ST, and 58% to 95% ST for V3, V4 and V5 videos, creaminess was less cited, with citations decreasing from 71.88% to 50%, 71.88% to 53.13%, and 67.19% to 51.56%, respectively.

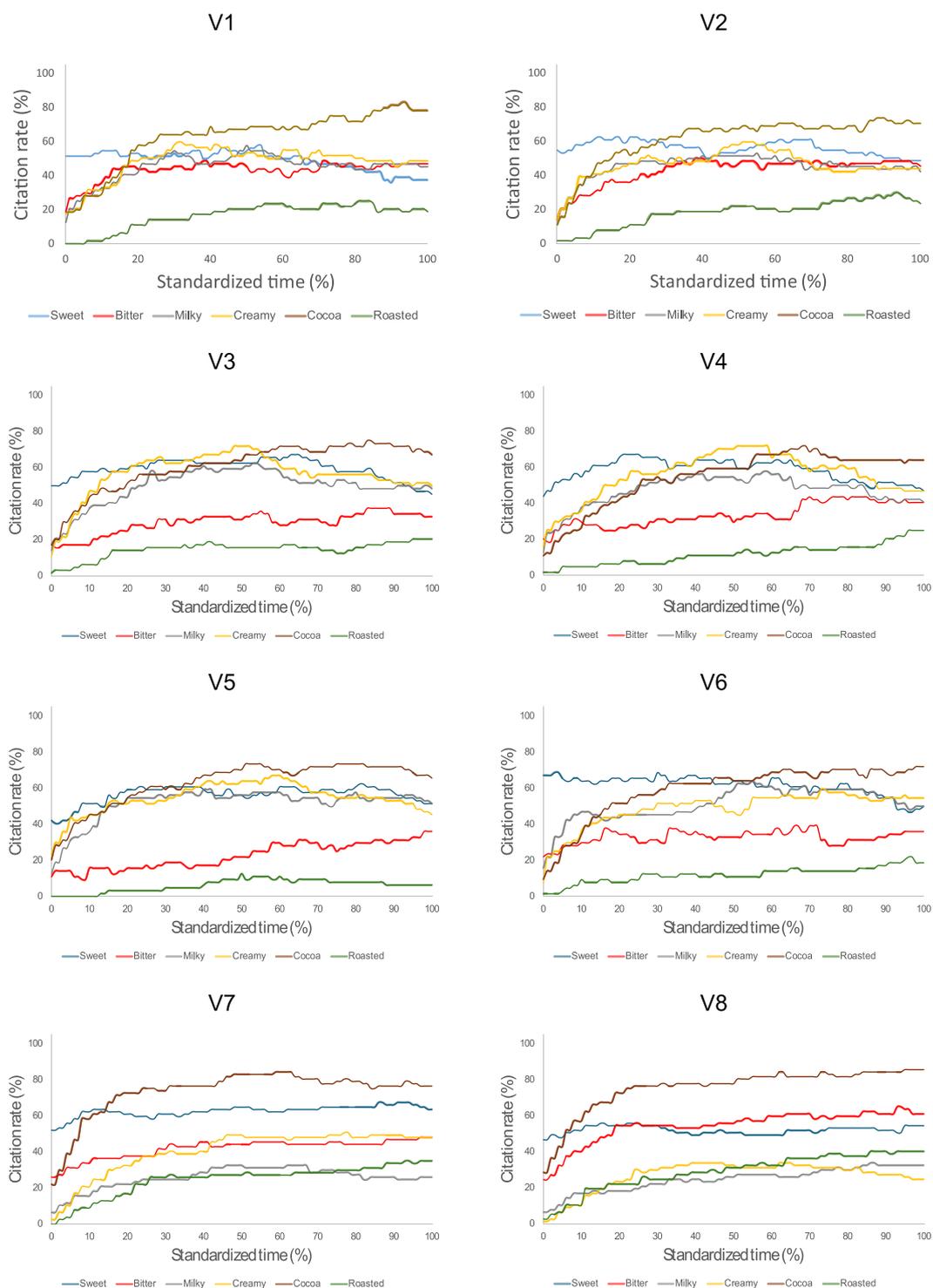
For the nature documentary video (V6), creaminess was increasingly cited from 1% to 22% ST, reaching a maximum citation rate of 45.31%. Creaminess was then steadily cited from 63% to 100% ST, with citation rates between 53.13% and 59.38%.

### 3.2.5 | Cocoa

In the nature documentary (V9) and scenic relaxation (V10) videos, cocoa was highly cited from 22% to 85% ST and 59% to 92% ST, with citation rates between 70.13 and 92.21% and 84.42% and 89.61%, respectively. In the classical crossover (V8 and V7) videos, cocoa was increasingly cited from 0% to 27% ST and 0% to 25% ST, reaching maximum citation rates of 76.62% and 75.32%, respectively.

### 3.2.6 | Roasted

In the classical crossover (V8 and V7) videos, roasted was increasingly cited from 11% to 100% ST and 17% to 100% ST, with



**FIGURE 2** | TCATA curves for chocolate ice cream consumed while watching the 10 videos (V1–V10; see Table 1) and a silent condition. Reference lines (highlighted) indicate those citation proportions that were statistically significant (thickened line) and not selected by chance.

citation rates between 19.48% and 40.26% and 15.58% and 35.06%, respectively.

### 3.3 | Correspondence Analysis

The results in Figure 2 present the overall TCATA curves for chocolate ice cream consumption while participants viewed 10 different videos. Only attributes that reached statistical signif-

icance (represented as augmented lines in the TCATA curves) will be discussed. To further summarize the TCATA results, the duration for which each attribute was selected was analyzed through CA. The results in Figure 3 demonstrate significant differences in the perception of chocolate ice cream consumed in across the 10 videos ( $c2(50) = 7761.94; p < 0.05$ ), with Dimension 1 accounting for 81.14% of the variance. For the classical crossover (V8) video, ice cream samples showed high positive scores that correlated with bitter and roasted attributes. Under the silent,

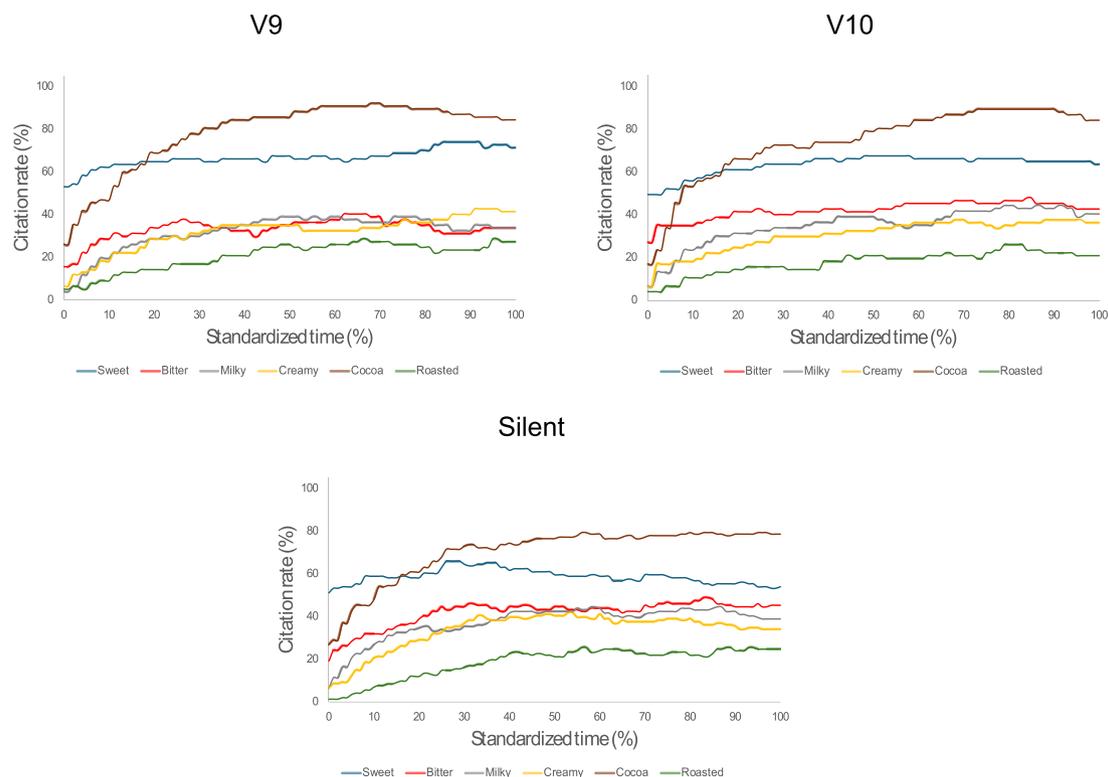


FIGURE 2 | (Continued)

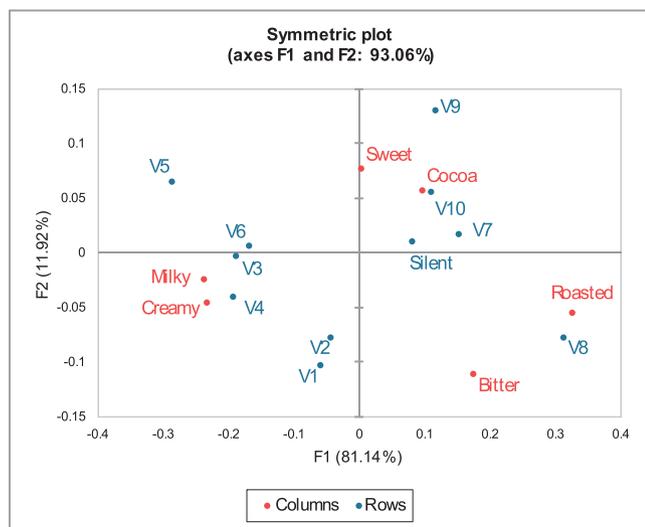


FIGURE 3 | The first two components of the correspondence analysis factor map based on aggregated TCATA data over the whole evaluation duration. Different colors represent the video conditions (blue) and sensory attributes (red).

classical crossover (V7), and scenic relaxation (V10) videos, ice cream samples had high positive scores, correlating with the cocoa attribute. On the contrary, samples consumed under scenic relaxation (V4), nature documentary (V5 and V6), and animation and adventure (V3) videos demonstrated high negative scores along dimension 1, which were further associated with the milky and creamy characteristics. Dimension 2 accounted for 11.92% of the variance, with ice cream samples consumed under the nature documentary (V9) video having a high positive score correlated

with sweetness, while the action (V1 and V2) videos showed a negative score inversely related to sweetness.

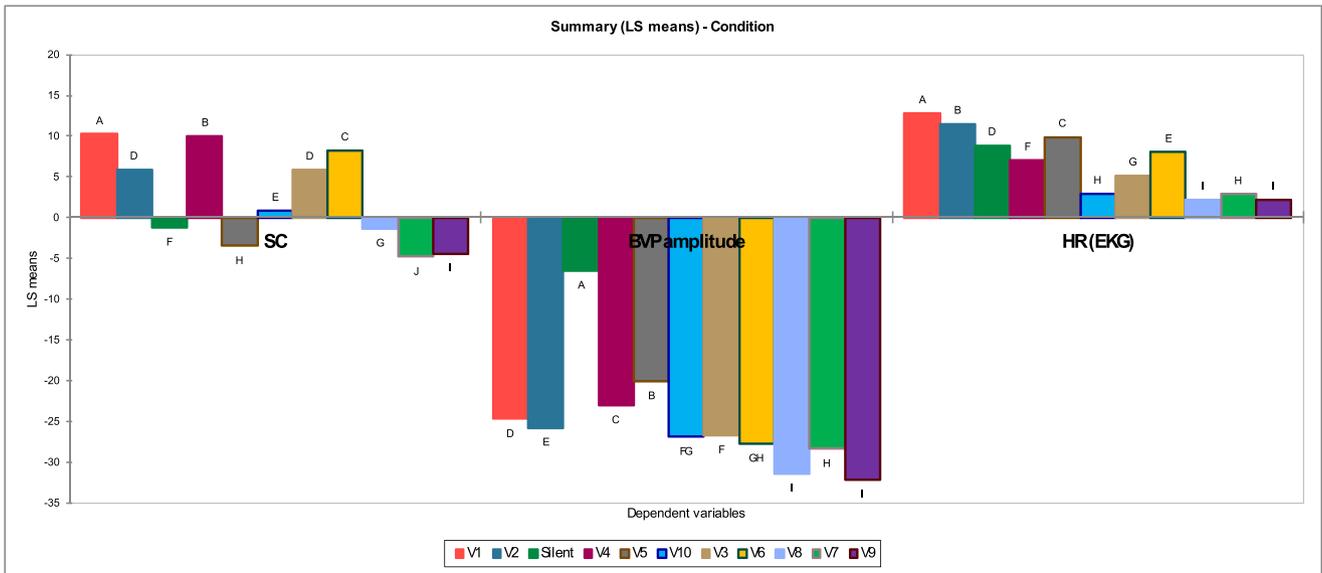
### 3.4 | Electrophysiological Responses

#### 3.4.1 | Electrophysiological Change Scores During Consumption of Chocolate Ice Cream Under Different Video Conditions

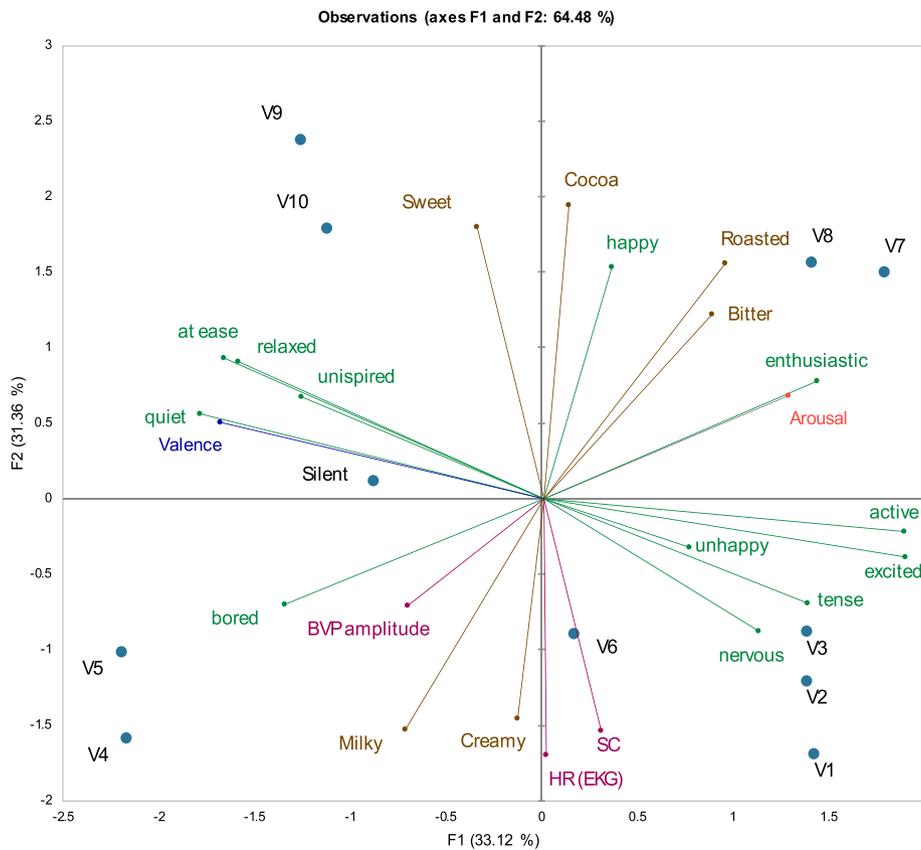
The results of the one-way repeated measures ANOVA revealed significant effects of video type on SC ( $F(71, 703) = 26637.385, p < 0.01$ ), BVP amplitude ( $F(71, 703) = 248.590, p < 0.01$ ), and HR ( $F(71, 703) = 605.316, p < 0.01$ ). In terms of physiological measures (Figure 4), SC was significantly higher for the action (V1 and V2), animation and adventure (V3), scenic relaxation (V4 and V10), and nature documentary (V6 and V9) videos. BVP amplitude was significantly lower under the animation and adventure (V3), classical crossover (V7 and V8), nature documentary (V6 and V9), and scenic relaxation (V10) videos. HR was significantly higher for the action (V1 and V2) videos, but was significantly lower for the classical crossover (V7 and V8), nature documentary (V9), and scenic relaxation (V10) videos.

### 3.5 | Multiple Factor Analysis (MFA) of Sensory, Emotional, and Electrophysiological Responses Obtained When Consuming Chocolate Ice Cream While Watching Videos (V1–V10)

The MFA biplot in Figure 5 illustrates the relationship between electrophysiological measures, emotion ratings, and the percep-



**FIGURE 4** | Electrophysiological change values (Equation 1) for skin conductance (SC), blood volume pulse (BVP) amplitude, and heart rate (HR) as a function of video (V). Different small letters (a–j) indicate significant changes in electrophysiological measure values. Video genres are as follows: V1: action, thriller, and military; V2: action, horror, and war; V3: animation and adventure; V4: scenic relaxation; V5: nature documentary; V6: nature documentary; V7: classical crossover; V8: classical crossover; V9: nature documentary; V10: scenic relaxation.



**FIGURE 5** | Multiple factor analysis (MFA) biplot of factor 1 and factor 2 for electrophysiological responses (purple), emotion ratings (green), perceptual attributes (brown), and affective responses (blue and red) for chocolate ice cream consumed under 10 different video conditions.

tion of ice cream across the different videos. F1 and F2 explained a total of 64.48% of the total variance.

F1 explained 33.12% of the variance and differentiated the samples consumed in the high arousal conditions (V1, V2, V3, V7, and V8) from those consumed under the high pleasantness conditions (silent, V4, and V5; Figure 5). Chocolate ice cream samples consumed while viewing the classical crossover (V7 and V8) videos had high positive scores along F1 that were correlated with arousal; the emotions of enthusiasm and happiness; and perceptions of bitterness, roastedness, and cocoa. Chocolate ice cream samples consumed while watching the action (V1 and V2) videos had high positive scores along F1 that were correlated with the emotions of unhappiness, tension, and nervousness. Chocolate ice cream samples consumed while viewing the animation and adventure (V3) video had high positive scores along F1 that were correlated with the emotions of activity and excitement.

Chocolate ice cream samples consumed in silence had high negative scores along F1 that were correlated with the emotions of feeling uninspired, relaxed, at ease, and quiet, as well as pleasantness. Chocolate ice cream samples consumed while viewing the scenic relaxation (V4) and nature documentary (V5) videos had high positive scores along F1 that were correlated with boredom and BVP amplitude.

F2 explained 31.36% of the variance and differentiated the samples consumed under the nature documentary (V9), and scenic relaxation (V10) videos had high positive scores along F2 and were correlated with sweetness ratings. Chocolate ice cream samples consumed while watching the nature documentary (V6) had high negative scores along F2 that were correlated with milkiness and creamy attributes, as well as increased SC and HR measures.

### 3.6 | Dynamic Bayesian Network

#### 3.6.1 | Network Organization Showing the Interactions Between Affective States, Emotions, Electrophysiological Measures, and the Perception of Ice Cream

The dynamic BN model (Figure 6) was employed to explore network organization encompassing ice cream perception, emotions, affective responses, and electrophysiological measures. This model provided an insight into how various emotional and electrophysiological measures influence the perception of chocolate ice cream, revealing notable associations.

HR was found to have a positive relationship with the emotion of happiness, which, in turn, positively influenced the sensation of sweetness. Moreover, a positive correlation was observed between HR and the emotion of enthusiasm. SC exhibited a positive correlation with feelings of relaxation and the perception of milkiness, while displaying a negative correlation with the perception of creaminess. BVP amplitude was found to have a negative correlation with both arousal and an active state. Furthermore, arousal showed a negative correlation with the perception of cocoa, while pleasantness demonstrated a negative correlation with both active and excited emotions. Additionally, the emotions of quiet and excited were positively associated with

the perception of creaminess, whereas tension was positively associated with roasted flavors.

### 3.7 | Liking of the Chocolate Ice Cream Consumed Under Different Video Conditions

The results of an one-way repeated measures ANOVA showed significant effects of video on mean liking ( $F(150, 832) = 3.979, p < 0.01$ ) measures (Figure 7). Liking was significantly higher when ice cream was consumed while viewing the nature documentary (V9) compared to the action (V1 and V2), and scenic relaxation with water sound (V4) videos.

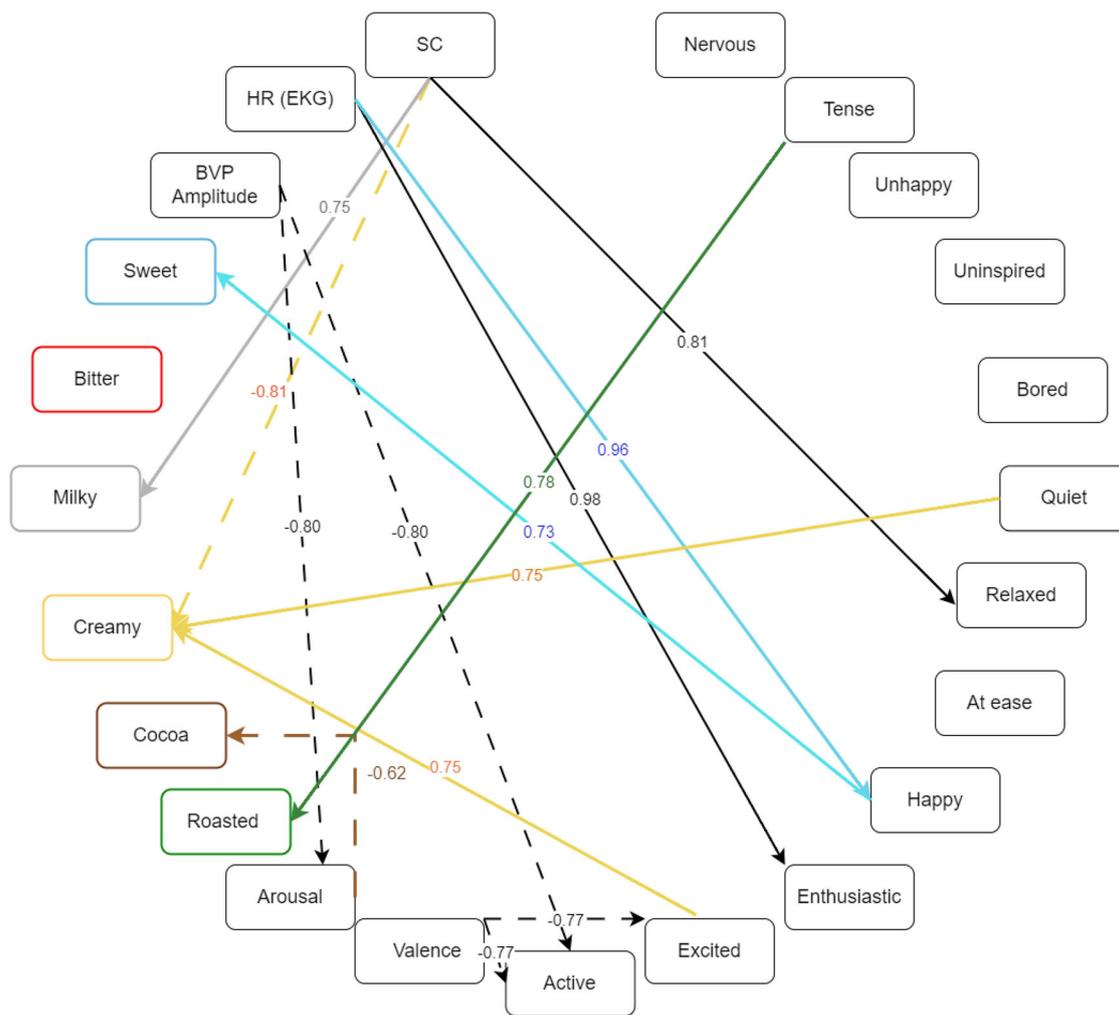
## 4 | Discussion

This research aimed to investigate how viewing videos that evoke different emotional responses can affect the flavor perception of chocolate ice cream. The discussion will focus on how audiovisual stimuli can impact the perception of chocolate ice cream, and how the perceptual attributes can be directly linked to either emotion or electrophysiological measures using the BN model.

1. How do videos that evoke different emotions influence sensory perception of chocolate ice cream?

In this study, a subsection of the videos were classified as classical crossover music videos (V7 and V8), characterized by the fusion of classical music elements with genres like pop, rock, or electronic. These videos feature artists performing with traditional classical instruments enhanced by modern techniques to create a unique blend of music and visuals. The classical crossover videos used in this research increased arousal levels, enhanced perceptions of bitterness, roastedness and cocoa, and induced felt emotions such as happiness and enthusiasm. The findings of this study highlight the significant role played by both the awareness of emotions and the immersive context in shaping perceptual processes when consuming food. These findings align with Zushi et al.'s (2023) study, which demonstrated that anxiety induced through specific video clips was linked to an increase in the perception of bitterness in sweetened and unsweetened coffee, especially when participants were mindful of their emotional state. Conversely, sweetness was suppressed under conditions of anxiety, irrespective of emotional awareness, with the authors suggesting that cognitive awareness of negative emotions may intensify bitterness perception while the suppression of sweetness could be attributed to unconscious physiological changes.

The action movie trailer videos (V1 and V2) were found to be correlated with negative emotions such as unhappiness, tension, and nervousness, and negatively correlated with sweetness ratings. In a related study by Zushi et al. (2021), the impact of emotional states induced by different movie genres (comedy, horror, and documentary) on the perceived sweetness of fruit juice was investigated. The findings revealed a significant reduction in sweetness ratings among participants who viewed the horror movie, which evoked negative emotions such as anxiety, fear, tension, and nervousness. Expanding on this research, Zushi et al. (2023) further reported that anxiety and stress, as induced by an anxiety-inducing horror video ('Dark Water'), reduced the



**FIGURE 6** | An integrated dynamic Bayesian network is used to represent the community structures and interactions among perception, emotions, affective states (i.e., valence and arousal), and electrophysiological measures during the consumption of chocolate ice cream. The conditional probabilities are the direct causal strengths evaluated with the standardized variables. Black nodes represent affect, emotion, and electrophysiological measures. Color nodes represent different perceptual attributes. Solid directional connectors represent positive correlations, and the dashed directional connectors indicate a negative correlation.

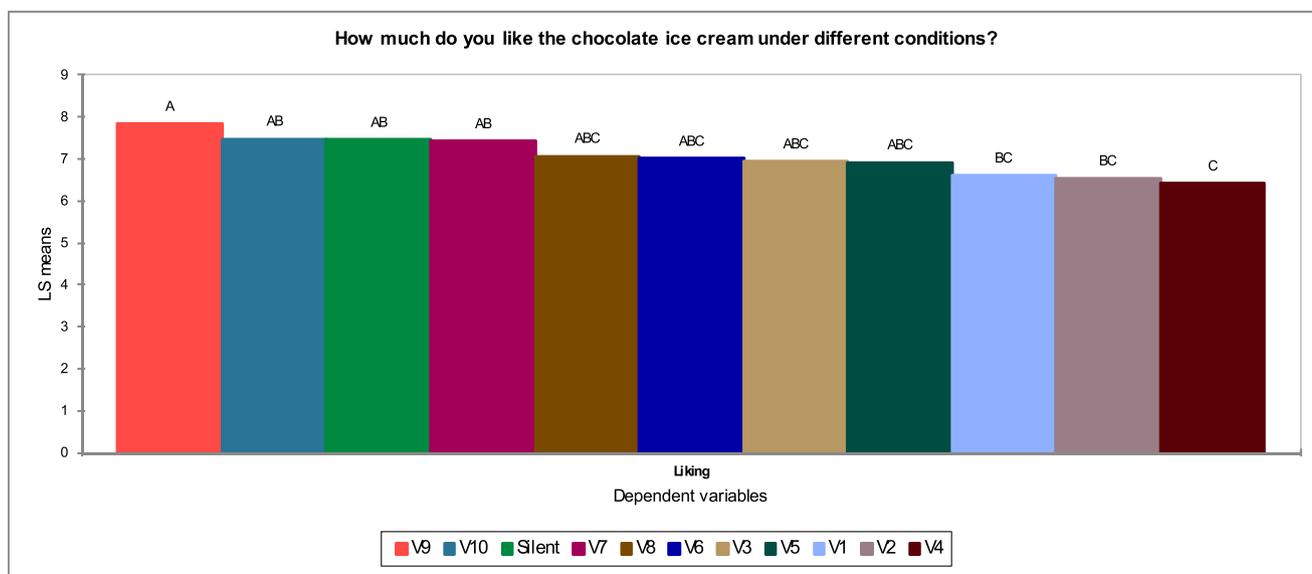
ratings of sweetness, bitterness, and umami in both sweetened and unsweetened coffee when compared to a relaxing video ('Next Journey').

The nature documentary (V9) and scenic relaxation (V10) videos used in the current study were found to be correlated with sweetness ratings. Similarly, in the study by Zushi et al. (2021), a neutral emotional state induced by viewing a documentary increased sweetness ratings, while fear induced by viewing a horror movie decreased them. Building on this, Zushi et al. (2023) showed that relaxation induced through a soothing sightseeing video either maintained or augmented the sweetness of coffee. Additionally, Kong et al. (2020) reported that a VR environment presenting a relaxing sightseeing tour also elicited positive emotional responses that correlated with an enhanced perception of sweetness, particularly in milk and white chocolates. Consistent with previous research, the nature documentary (V6) used in the current study was found to be positively correlated with perceptions of milkiness and creaminess. Together, these studies emphasize the important role of emotional states in

influencing food perception, illustrating that positive or neutral emotional states akin to those evoked by nature documentaries can positively enhance the perceptual attributes of food.

## 2. Electrophysiological measures obtained while watching different videos co-varied with the perception of ice cream.

Consuming ice cream while watching different video genres was found to significantly impact electrophysiological measures such as SC, HR, and BVP amplitude, which in turn correlated with perceptions of milkiness, creaminess, sweetness, bitterness, and cocoa and roasted flavors in chocolate ice cream. This study shows that there was a significant increase in SC and HR during the viewing of a nature documentary (V6) video, which was associated with milkiness and creaminess attributes. Kantono et al. (2019) investigated changes in chocolate gelato flavor while listening to music varying in liking, and examined the relationship between electrophysiological measures and perception using factor models. The results showed that SC and BVP amplitude responses were positively correlated with ratings of creaminess,



**FIGURE 7** | Liking of the chocolate ice cream consumed while watching videos (Table 1). Mean of video conditions with different small letters (a–j) indicates significant differences in average liking values.

while HR was positively correlated with milkiness. Furthermore, Xu et al. (2019b) reported that consuming ice cream in a university study area elicited perceptions of cocoa and milkiness, which were associated with felt emotions of lost and composed, and which were accompanied by an increase HR.

The current analysis revealed that viewing scenic relaxation (V10) and nature documentary (V9) videos significantly decreased BVP amplitude and HR, which in turn were positively correlated with sweetness ratings. A study conducted by Benz et al. (2022) that investigated a relaxation video intervention featuring various nature scenes reported a significant decrease in HR and an increase in parasympathetic dominance. Furthermore, Tsutsumi et al. (2017) explored the impact of viewing preferred video content depicting sea or forest environments upon relaxation levels and found a significant decrease in HR while noting a sustained increase in arousal level, suggesting a calming effect. Chang et al. (2008), championing the use of BVP amplitude to assess changes in sympathetic arousal, found that exposure to natural, restorative environments led to an increase in BVP amplitude, indicating decreased sympathetic arousal and increased relaxation.

To date, no studies have investigated how changes in electrophysiological measures when consuming food while viewing videos influenced flavor perception. Most studies that have correlated electrophysiological and flavor perception measures have examined the effects of music, sounds, and environmental context. Kantono et al. (2019) explored the relationship between electrophysiological measures and perceptions of chocolate ice cream, reporting that BVP amplitude was positively correlated to perceptions of sweetness and creaminess, while HR was negatively correlated to perceptions of sweetness and creaminess. Moreover, Xu et al. (2019a) found that listening to a café-forest soundscape was associated with sweetness ratings of chocolate ice cream. This auditory experience also resulted in a significant increase in BVP amplitude and decrease in HR. Similarly, in another study by Xu et al. (2019b), a café environment, which

elicited perceptions of sweetness, cocoa, and milkiness associated with positive emotions, also led to an increase in BVP amplitude. This suggests that an increase in BVP amplitude and decrease in HR may be associated with increased sweetness perceptions, supporting the results in this study.

The classical crossover (V7 and V8) videos were linked to a significant decrease in BVP amplitude and were correlated with arousal and feelings of enthusiasm and happiness, along with an increased perception of bitterness, and roasted and cocoa flavors. Classical crossover is a unique musical genre that combines classical music elements with popular music styles, characterized by moderate-to-high tempo music. In a study by Dillman Carpentier and Potter (2007), the impact of tempo variations on sympathetic arousal was investigated using six auditory stimuli that represented different tempos and genres. This included slow classical, fast classical, slow rock, fast rock, and two segments of silence. Their findings revealed a significant interaction between genre and tempo: an increase in tempo led to heightened sympathetic arousal for classical music but decreased sympathetic activation for rock music.

The observed association between decreased BVP amplitude and perceptions of bitterness, and roasted and cocoa flavors can be understood through the complex interplay between electrophysiological responses and sensory perception. Supporting the current findings, Kantono et al. (2019) reported that BVP amplitude was negatively correlated to perceptions of bitterness, milkiness, and creaminess of ice cream. Furthermore, Xu et al. (2019a) found that listening to a café-machine soundscape was associated with bitterness and perceptions of roasted flavors of chocolate ice cream. This result was associated with a significant decrease in BVP amplitude, indicating increased arousal and stress. In Xu et al. (2019b), a bus stop environment elicited bitterness and roasted flavor perceptions that in turn were associated with negative emotions, and also with decreased BVP amplitude, indicating heightened stress in response to the less pleasant setting. While Xu et al.'s studies did not directly examine arousing

music videos, they provided insights into how multisensory input can co-vary with electrophysiological responses.

3. Flavor perception is related to self-report emotion and electrophysiological measures.

The perception of food is related to subjective emotions and electrophysiological measures, as demonstrated by the Bayesian network (BN) model used in this study. The BN model was applied to examine the relationships between ice cream perception, felt emotions, and electrophysiological indices that represent objectively measured affective states uncontaminated by response bias. Unlike traditional statistical models, the BN model can handle complex and interdependent variables, which in the current study provided valuable insights into how felt emotion and electrophysiological measures relate to the perceptions of ice cream. The findings showed significant correlations between electrophysiological measures, felt emotions, and flavor perception.

Studies have demonstrated that emotional states can influence food perception. In the current study, a neutral emotion “quiet” and a positive emotion “excitement” evoked by videos were positively correlated with creaminess, while happiness was positively correlated with sweetness. Jaeger et al. (2019) found that perceptual attributes such as sweetness and creaminess were positively correlated with feelings of pleasure and arousal. Similarly, Jaeger et al. (2022) demonstrated that dairy products with creamy textures were either associated with calm and passive feelings, or quiet and excited emotions. Again, a strong association between sweetness and happiness was noted by Jaeger et al., with sweet products like chocolates and sweet snacks consistently eliciting feelings of happiness and satisfaction. Conversely, in the current study, the negative emotion of tension was found to be correlated with the perception of roasted flavors. Among the studies reviewed, only Xu et al. (2019b) observed that consuming chocolate ice cream in a bus stop environment evoked negative emotions (tension, fatigue, anxiety, annoyance, difficulty concentrating, dissatisfaction, and uncertainty), resulting in increased ratings of bitterness and roasted flavors.

The BN showed a positive relationship between SC and milkiness ratings, and a negative correlation with SC and creaminess. The study by W. He et al. (2017) reported that SC decreased significantly after participants consumed creamy foods, indicating lower physiological arousal post-consumption. Thus, it may be that creamy foods tend to reduced arousal, as reflected in the decreased SC levels, supporting its use as a ‘comfort food’ (Tomiyama et al. 2015). Interestingly, Kantono et al. (2019) found that SC was negatively correlated with creaminess ratings and positively correlated with milkiness. The results of the current study support the findings of Kantono et al. (2019) and can be attributed to the varying experimental conditions. Kantono et al. (2019) investigated the influence of music varying in pleasantness on the flavor perception of chocolate ice cream, while the current study explored the impact of audio-visual video stimuli likewise designed to evoke a range of emotions.

A negative correlation was found between BVP amplitude and arousal levels using the BN model, which would be expected. Jang et al. (2014) investigated the relationship between affective

dimensions, such as arousal and pleasantness, and electrophysiological measures. Their study found that emotions associated with higher arousal levels, such as fear, anger, and surprise, showed a positive association with HR and skin conductance. Conversely, these emotions exhibited a negative relationship with BVP amplitude and pulse transit time. Therefore, the negative correlation between BVP amplitude and arousal levels observed in the current BN model is consistent with the findings of Jang et al. (2014), who reported that emotions associated with higher arousal, such as fear, anger, and surprise, showed a negative relationship with BVP.

## 5 | Conclusion

This study presents a novel perspective on how emotions evoked by video content can potentially influence the perception of chocolate ice cream. Videos eliciting strong negative emotions were associated with an increase in BVP amplitude, which in turn influenced the perception of bitterness, and both cocoa and roasted flavors. Conversely, videos that evoke pleasant emotions were linked to an increase in SC and HR, influencing the perception of sweetness, milkiness, and creaminess. Using a BN, the findings reveal a complex relationship between perception, emotional states, and their underlying somatic responses. This comprehensive BN model framework advances the understanding of the interconnections between sensory inputs, emotional reactions, and electrophysiological processes, enhancing the existing body of knowledge with its dynamic representation of these interactions. However, the study manifests several potential limitations that should be addressed in future research, such as the reliance on specific video content to elicit emotional states, the use of chocolate ice cream as a stimuli limits generalizability, and the laboratory setting potentially degrades external validity. Future research could explore a wider range of food products, incorporate a wider range of audiovisual stimuli, adapt immersive virtual reality technology, and employ more naturalistic settings to enhance the robustness and applicability of the findings.

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### Conflicts of Interest

The authors declare no conflicts of interest.

### Data Availability Statement

The main author (YHTL), corresponding (NH), and one of the coauthor (KK) confirms that we have full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Data are available upon request, and the request can be directed to the main author (YHTL), corresponding (NH), and one of the coauthor (KK).

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## Videos used in the preliminary study

No.	Video/Link
D1	A world of calm <a href="https://www.youtube.com/watch?v=5nVACafZAJw">https://www.youtube.com/watch?v=5nVACafZAJw</a> (accessed on July 26, 2022)
D2	Antarctica <a href="https://www.youtube.com/watch?v=m4LnMIESzWA">https://www.youtube.com/watch?v=m4LnMIESzWA</a> (accessed on July 26, 2022)
D3	Planet ocean <a href="https://www.youtube.com/watch?v=etExgF52XlQ">https://www.youtube.com/watch?v=etExgF52XlQ</a> (accessed on July 26, 2022)
D4	Iceland—The land of fire and ice <a href="https://www.youtube.com/watch?v=AVHozwCteL4">https://www.youtube.com/watch?v=AVHozwCteL4</a> (accessed on July 26, 2022)
D5	Secrets of the sea <a href="https://www.youtube.com/watch?v=zY4cdXIQaBA">https://www.youtube.com/watch?v=zY4cdXIQaBA</a> (accessed on July 26, 2022)
C1	The last letter from your lover (2021) <a href="https://www.youtube.com/watch?v=Y-I3DuUOsNw">https://www.youtube.com/watch?v=Y-I3DuUOsNw</a> (accessed on July 15, 2022)
C2	Things heard & seen <a href="https://www.youtube.com/watch?v=HCAaonjgDEA">https://www.youtube.com/watch?v=HCAaonjgDEA</a> (accessed on July 15, 2022)
C3	The dig <a href="https://www.youtube.com/watch?v=JZQz0rkNajo">https://www.youtube.com/watch?v=JZQz0rkNajo</a> (accessed on July 15, 2022)
E1	Without remorse <a href="https://www.youtube.com/watch?v=e-rw2cxFVLg&amp;t=12s">https://www.youtube.com/watch?v=e-rw2cxFVLg&amp;t=12s</a> (accessed on July 15, 2022)
E2	Shadow in the cloud <a href="https://www.youtube.com/watch?v=XjLnk8YriCQ">https://www.youtube.com/watch?v=XjLnk8YriCQ</a> (accessed on July 15, 2022)
E3	Space jam: A new legacy <a href="https://www.youtube.com/watch?v=olXYZosXw_ov">https://www.youtube.com/watch?v=olXYZosXw_ov</a> (accessed on July 15, 2022)
A1	3D scan of Tham Luang Cave   Drain the oceans: Thai cave rescue   National Geographic UK <a href="https://www.youtube.com/watch?v=Buda6f3n16g">https://www.youtube.com/watch?v=Buda6f3n16g</a> (accessed on Aug 11, 2022)
A4	My dinner with Andre trailer <a href="https://www.youtube.com/watch?v=n7hSYOQOkII&amp;list=PLk8WSFg0BU7R2E8x8KlGXxBz48KITd7O&amp;index=41">https://www.youtube.com/watch?v=n7hSYOQOkII&amp;list=PLk8WSFg0BU7R2E8x8KlGXxBz48KITd7O&amp;index=41</a> (accessed on Aug 11, 2022)
A5	The story of film: An Odyssey trailer <a href="https://www.youtube.com/watch?v=IWz4Q3xOeqM&amp;list=PLk8WSFg0BU7R2E8x8KlGXxBz48KITd7O&amp;index=63">https://www.youtube.com/watch?v=IWz4Q3xOeqM&amp;list=PLk8WSFg0BU7R2E8x8KlGXxBz48KITd7O&amp;index=63</a> (accessed on Aug 11, 2022)
A9	Dracula (1931)—Don't look in the mirror (HD) <a href="https://www.youtube.com/watch?v=_iHw8ArJQyg&amp;list=PLk8WSFg0BU7R2E8x8KlGXxBz48KITd7O&amp;index=32">https://www.youtube.com/watch?v=_iHw8ArJQyg&amp;list=PLk8WSFg0BU7R2E8x8KlGXxBz48KITd7O&amp;index=32</a> (accessed on Aug 11, 2022)
A10	Hermia & Helena—Official trailer <a href="https://www.youtube.com/watch?v=tGkO7t05yPE&amp;list=PLk8WSFg0BU7R2E8x8KlGXxBz48KITd7O&amp;index=38">https://www.youtube.com/watch?v=tGkO7t05yPE&amp;list=PLk8WSFg0BU7R2E8x8KlGXxBz48KITd7O&amp;index=38</a> (accessed on Aug 11, 2022)
A11	4K Winter waterfall scene—Probiy Waterfall, the Carpathians, Ukraine—Trailer 49 <a href="https://www.youtube.com/watch?v=x8tvYjRxXno&amp;t=31s">https://www.youtube.com/watch?v=x8tvYjRxXno&amp;t=31s</a> (accessed on Aug 11, 2022)
A12	Sky: Children of the light—The journey so far   AnimeJapan Trailer <a href="https://www.youtube.com/watch?v=IsbrHWMZXn4">https://www.youtube.com/watch?v=IsbrHWMZXn4</a> (accessed on Aug 11, 2022)
A13	Dolby presents: “Universe”   Trailer   Dolby <a href="https://www.youtube.com/watch?v=hesv-etwK_o">https://www.youtube.com/watch?v=hesv-etwK_o</a> (accessed on Aug 11, 2022)
H1	Ed's Heinz Ad <a href="https://www.youtube.com/watch?v=keOaQm6RpBg">https://www.youtube.com/watch?v=keOaQm6RpBg</a> (accessed on June 28, 2023)
H2	Despicable me 2—Happy (movie scene) <a href="https://www.youtube.com/watch?v=CJ9Tdvqlo_Y">https://www.youtube.com/watch?v=CJ9Tdvqlo_Y</a> (accessed on June 28, 2023)
H3	Shakira—Don't wait up (alternate version) <a href="https://www.youtube.com/watch?v=fTlMsvTjLFQ">https://www.youtube.com/watch?v=fTlMsvTjLFQ</a> (accessed on June 28, 2023)
H4	HAUSER—Swan Lake <a href="https://www.youtube.com/watch?v=KTRnuoVp2HM">https://www.youtube.com/watch?v=KTRnuoVp2HM</a> (accessed on June 28, 2023)
H5	2CELLOS—Pirates of the Caribbean [OFFICIAL VIDEO] <a href="https://www.youtube.com/watch?v=Xj3gU3jACe8">https://www.youtube.com/watch?v=Xj3gU3jACe8</a> (accessed on June 28, 2023)
H6	Céline Dion—Love again <a href="https://www.youtube.com/watch?v=FU7c6sJiiYE">https://www.youtube.com/watch?v=FU7c6sJiiYE</a> (accessed on June 28, 2023)
H7	Taylor Swift ft. Ice Spice—Karma <a href="https://www.youtube.com/watch?v=XzOvgu3GPwY">https://www.youtube.com/watch?v=XzOvgu3GPwY</a> (accessed on June 28, 2023)
H8	Vanessa-Mae—Storm (official video) <a href="https://www.youtube.com/watch?v=mdFrn89x74k">https://www.youtube.com/watch?v=mdFrn89x74k</a> (accessed on June 28, 2023)
H9	The lord of the rings: The rings of power <a href="https://www.youtube.com/watch?v=x8UAUAuKNcU">https://www.youtube.com/watch?v=x8UAUAuKNcU</a> (accessed on June 28, 2023)
H10	HAUSER—Pas de Deux (The Nutcracker) <a href="https://www.youtube.com/watch?v=0IWEQLaf9zs">https://www.youtube.com/watch?v=0IWEQLaf9zs</a> (accessed on June 28, 2023)
L3	The beauty of the rings of power <a href="https://www.youtube.com/watch?v=-0cT2TG1ki4">https://www.youtube.com/watch?v=-0cT2TG1ki4</a> (accessed on June 28, 2023)
L4	Luka ft. Evgeny <a href="https://www.youtube.com/watch?v=f68h6LTWD-E">https://www.youtube.com/watch?v=f68h6LTWD-E</a> (accessed on June 28, 2023)
L5	Patagonia 4K <a href="https://www.youtube.com/watch?v=DsXMR7dY35w">https://www.youtube.com/watch?v=DsXMR7dY35w</a> (accessed on June 28, 2023)
L6	Our planet   Coastal seas   Full episode   Netflix <a href="https://www.youtube.com/watch?v=r9PeYPHdpNo">https://www.youtube.com/watch?v=r9PeYPHdpNo</a> (accessed on June 28, 2023)
B1	Australian beaches DVD—Relax with ocean bay beach ocean sounds <a href="https://www.youtube.com/watch?v=dExver_sdV4">https://www.youtube.com/watch?v=dExver_sdV4</a> (accessed on June 28, 2023)

(Continues)

No.	Video/Link
B4	The fascinating wildlife in deep mountain lakes <a href="https://www.youtube.com/watch?v=aInkqzdmf0">https://www.youtube.com/watch?v=aInkqzdmf0</a> (accessed on June 28, 2023)
B5	One hour of amazing ocean moments   BBC Earth <a href="https://www.youtube.com/watch?v=CSgDjZ_Vv8g">https://www.youtube.com/watch?v=CSgDjZ_Vv8g</a> (accessed on June 28, 2023)
B10	Fine dining   Commercial video production by unmanned AV <a href="https://www.youtube.com/watch?v=-MdohXec7M">https://www.youtube.com/watch?v=-MdohXec7M</a> (accessed on June 28, 2023)
B13	Inside the Mangrove Forest <a href="https://www.youtube.com/watch?v=cwTZhyA57mA">https://www.youtube.com/watch?v=cwTZhyA57mA</a> (accessed on June 28, 2023)
B15	Tiaki & the guardians #AirNZSafetyVideo <a href="https://www.youtube.com/watch?v=BsAO0Lle59I">https://www.youtube.com/watch?v=BsAO0Lle59I</a> (accessed on June 28, 2023)

Note: In a preliminary test, participants viewed videos and indicated their emotions while doing so, The collected data was further analysed using correspondence analysis (CA) to determine which videos will be used in the actual study. (Appendix 2).

The first two components of the correspondence analysis (CA) factor map based on emotions matched with videos. Different colors represent the emotion (blue) and video condition (red)

Videos used in the current study

Sensory attributes and descriptions of chocolate ice cream

Sensory attributes	Description	Reference standard
Sweet (taste)	Taste associated with sugar	Hershey Milk chocolate
Bitter (taste)	Taste associated with caffeine or quinine solutions	Hershey Dark chocolate
Cocoa (flavor)	Characteristic flavor associated with cocoa	Hershey Milk chocolate
Milky (flavor)	Characteristic flavor associated with milk	Fresh milk (Anchor, New Zealand)
Creamy (texture)	Texture associated with cream	Fresh cream (Anchor, New Zealand)
Roasted (flavor)	A burnt, somewhat bitter character present in a product that has been cooked at a high temperature, typical of very strong dark coffee	Hershey Milk chocolate + 3 highly roasted coffee beans

Descriptions and examples of emotion terms used in this experiment.

<b>Emotion</b>	<b>Description</b>	<b>Example</b>
Active	Engaging in physically energetic pursuits.	“Although he was seventy, he was still robust and active.”
At ease	Free from worry or awkwardness.	“She was never quite at ease with Phil.”
Bored	Feeling weary and impatient because one is unoccupied or lacks interest in one’s current activity.	“She got bored with staring out of the window.”
Excited	Very enthusiastic and eager.	“They were excited about the prospect.”
Enthusiastic	Having intense enjoyment, interest, or approval.	“He could be wildly enthusiastic about a project.”
Happy	Feeling of pleasure or contentment.	“I’m happy with his performance.”
Nervous	(Of a feeling or reaction) resulting from anxiety or anticipation.	“Staying in the house on her own made her nervous”
Quiet	Feeling without much activity, disturbance, or excitement.	“The street below was quiet, little traffic braving the snow.”
Relaxed	Free from tension and anxiety.	“We were having a great time and feeling very relaxed.”
Tense	Unable to relax because of nervousness, anxiety, or stimulation.	“He was tense with excitement.”
Uninspired	(Of a person) not filled with excitement.	“If I’m feeling uninspired by the roles coming my way.”
Unhappy	Not happy. Not satisfied or pleased with (a situation).	“He was unhappy about something.”