Title

Sound pleasantness influences the perception of emotional and non-emotional foods

Yi Hsuan Tiffany Lin[a], Nazimah Hamid[a]*, Daniel Shepherd[b], Kevin Kantono[a], & Charles Spence[c]

[a] Department of Food Science, Auckland University of Technology, Private Bag

92006, Auckland 1142, New Zealand

[b] Department of Psychology, Auckland University of Technology, Private Bag 92006, Auckland 1142, New Zealand

[c] Crossmodal Research Laboratory, Department of Experimental Psychology, New Radcliffe House, University of Oxford, Oxford, OX2 6GG, UK

*Corresponding author: E-mail address: nazimah.hamid@aut.ac.nz; Telephone: +64 9 921 9999 Ext. 6453.

Highlights

- Tasting emotional food evoked more emotions than non-emotional food.
- Emotions varied when consuming food in sound conditions that varied in pleasantness.
- Pleasantness of the sound conditions influenced the dominant sensory attributes of foods.
- Emotions influenced sensory attributes of foods consumed in different sound conditions.

Keywords

Emotional foods; chocolate, vegetable ice cream, pleasant sound; emotions; Temporal Dominance of Sensations

Abstract

Sounds elicit emotional responses that can influence the perception of food. However, the effects of sounds upon the perception of emotional or non-emotional foods have yet to be fully elucidated. The present study was designed to investigate how pleasant and unpleasant sounds influenced both perception and emotion responses during the consumption of chocolate milkshake (CM) and vegetable ice cream, representing emotional and non-emotional foods, respectively. The temporal changes in perceived flavour were documented using the temporal dominance of sensations (TDS) method. In addition, ratings of liking, affective states, and emotional state were determined following the consumption of milkshake and ice cream. Canonical variate analysis (CVA) was used to further summarize the standardized duration of flavour of CM, liked vegetable ice cream (LV), and less liked vegetable ice cream (LLV) consumed under different sound conditions. Multivariate analysis revealed significant differences between the standardized duration of flavours of CM, LV, and LLV perceived under the pleasant sound (PS) and unpleasant sound (US) conditions. Additionally, flavour perception, affective states, and emotional responses varied with CM, LV, and LLV under the PS and US conditions. These findings contribute to a better understanding of how sounds varying in pleasantness can influence the perceptual dynamics of emotional and non-emotional foods.

1. Introduction

Eating can influence mood and emotion, mainly by reducing arousal and irritability, and increasing calmness and positive affect (Gibson, 2006). Emotional eating has been shown to influence the quantity and type of food eaten. For instance, Konttinen et al. (2010) reported that men and women with higher emotional eating scores tended to consume more sweet and energy-dense foods, and these associations remained after adjustment for restrained eating and depressive symptoms. However, there were no associations between emotional eating and the consumption of fruits or vegetables for either gender. These findings indicate that certain foods can induce emotions ("emotional foods"). Fiegel et al. (2014) investigated the effect of background music (classical, jazz, hip-hop, and rock) on the flavour intensity, flavour pleasantness, texture impression, and overall impression of emotional and non-emotional food (milk chocolate and bell pepper, respectively). The authors found that the overall impression of chocolate was significantly higher with the jazz than the hip-hop and rock music stimuli. As for bell peppers, however, no significant effects of music genre on perception were reported.

Music influences the perception of food, with researchers showing that music conditions varying in terms of valence can influence flavour perception, as well as affective and emotional responses (Kantono et al., 2016, 2018, 2019; Xu et al., 2019a). Russell and Barrett (1999) describe affect as a feeling that defines how you feel in terms of at least two dimensions: how pleasant or unpleasant you feel (valence), and how calm or agitated you feel (arousal). In applied sensory and consumer research, the word 'emotion' is used to describe a brief emotional experience that is evoked by a product. Emotions are typically described as a conscious phenomenon that can be measured via verbal report (Delplanque et al., 2012; Porcherot et al., 2021), or 'emotional conceptualisations' (Thomson et al., 2010) and 'emotional associations' (Piqueras-Fiszman & Jaeger, 2014) that refer to concepts having an emotional connotation. Many of the studies that have investigated the effects of sound on food perception have been carried out using foods that contain chocolate. Eating chocolate has been shown to improve experimentally-induced negative mood states immediately, which could be attributed to its palatability (Macht & Mueller, 2007). Sounds varying in valence (i.e., pleasantness) can evoke emotions that, in turn, influence food perception. Seo and Hummel (2011) confirmed that pleasant sounds can amplify the pleasantness of floral odour (2-phenylethanol). Furthermore, a "sweet" soundtrack was shown to significantly increase the perceived sweetness of beer (Carvalho et al., 2016), while a "creamy" soundtrack increased the perceived sweetness and creaminess of chocolate (Carvalho et al., 2017). These perceptual changes were attributed to the emotions evoked during consumption. Xu et al. (2019a) reported that positive emotions were rated significantly higher while listening to café sounds overlaid by forest sounds, and associated with the sweetness attribute when consuming chocolate ice cream. Similarly, Lin et al. (2019) found that the sweet and creamy attributes of chocolate ice cream were dominant when their participants listened to pleasant park and café sound conditions. Kantono et al. (2016; 2018; 2019) confirmed that liked music eliciting positive emotions resulted in an increased dominance of sweetness, milky, and cocoa perceptions in a sample of chocolate ice cream.

Dynamic changes in perception can influence the liking of foods. Ares et al. (2017) found that the dynamic sensory profile of French bread and milk chocolate using the temporal dominance of sensation (TDS) approach influenced consumer's overall liking scores. Olegario et al. (2020) further explored the temporal aspects of the "healthy" and/or "free-from" versions of chocolate and milk coffee using the multiple-TDS method, higher overall liking was associated with chocolate that contained a higher level of cacao with dominant attributes of bitter, cocoa and crunchy. On the other hand, overall liking was higher for decaffeinated milk coffee with dominant attributes of sweetness, caramel and roasted. However, in the latter study, only 23 semi-trained assessors assessed overall liking. However, it has been suggested that a minimum of 50 consumer assessors is required when carrying out consumer testing (Vidal et al., 2014).

Perhaps unsurprisingly, emotions are elicited differentially by foods varying in terms of how much people liking them. Previous studies have shown that liked foods such as sweet snacks (Desmet & Schifferstein, 2008), chocolate (Cardello et al., 2012), chocolate milk (Pelsmaeker et al., 2013), and chocolate brownie (Piqueras-Fiszman & Jaeger, 2014) evoked greater emotional responses than less liked foods. In addition, liked foods such as fruit-flavoured dark chocolates (Jaeger et al., 2014), chocolate with sugar, and with tagatose (Lagast et al., 2018), premium milk chocolate (Schouteten et al., 2018), and berry beverages (Waehrens et al., 2018) evoked positive emotions. On the other hand, less liked foods such as dark chocolates (Jaeger et al., 2014), chocolate with stevia (Lagast et al., 2018), traditional milk chocolate (Schouteten et al., 2018), and vegetable beverages (Waehrens et al., 2018) tended to evoke more negative emotions. Recently, Samant and Seo (2020) reported that liked vegetable juices significantly increased mean ratings of positive emotions. In contrast, a low sodium organic vegetable drink, which was significantly less liked when consumed, elicited significantly higher reports of disgust, an innate and negative emotion.

The role of emotions and food liking have been subject to considerable scrutiny to help explain the dynamics of multisensory flavour perception. Understanding how emotions influence the perception of emotional and non-emotional foods while listening to sounds has, to date, attracted rather less attention in the literature. The objective of the present study was therefore to compare the perceptions of emotional (chocolate milkshake) and non-emotional (vegetable ice cream) foods while listening to sound conditions that varied in pleasantness. In addition, the emotional states of participants were determined to register how pleasant and unpleasant sounds influenced the perception of flavours with different food types. It was hypothesised that pleasant sounds would evoke positive affective responses in the participant, while amplifying ratings of the desirable sensory attributes of an emotional food (chocolate milkshake). On the other hand, unpleasant sound is hypothesised to induce negative affective states and, in turn, attenuate the desirable sensory attributes of emotional (chocolate milkshake) and non-emotional (vegetable ice creams) foods.

2. Materials and Methods

2.1 Sample preparation and presentation

Chocolate milkshake

Chocolate milkshakes (see Appendix 1) were purchased at a Wendy's fast-food restaurant located in the Auckland CBD, New Zealand. A pilot test carried out confirmed that the physical and sensory characteristics of the refrigerated milkshake were maintained for at least four hours after purchase. In this study, the chocolate milkshake was stored in the refrigerator at 4°C and consumed by participants within 3 hours of purchase.

Vegetable ice cream

Vegetable ice cream was chosen in this study as it was hypothesized to be a non-emotional food. A recent review by Spence and Youssef (2021) described various ways to enhance the food experience amongst the elderly due to a decline in chemical senses with aging. The addition of meal replacement powders and/or pureed vegetables into positively-valenced ice-cream has been suggested to be an effective means of delivering nutrients for the elderly (Spence et al., 2019). In the present research, a pilot test was carried out to determine the liking of seven vegetable ice creams (leek, eggplant, asparagus, broccoli, kale, celery, and spinach) using forty-two participants (25 females, 18 males) ranging from 18 to 50 years old (M_{age} = 28 years; SD_{age} = 5.92 years). The results are shown in Appendix 2. Eggplant ice cream (M_{liking} = 5.589, SD_{liking} = 2.55) was liked significantly more than the other ice creams (p < 0.001) followed by spinach, celery, asparagus, broccoli, kale, and leek. Broccoli, kale, and leek ice creams were significantly disliked and not chosen for use in the main study. The most liked eggplant and less liked asparagus ice creams were used in the study.

The vegetable ice cream samples contained a 14.29% vegetable puree that was incorporated into an ice formulation containing cream (57.14%), milk (14.29%), and sugar (14.29%). The vegetable puree was prepared by boiling vegetables (asparagus and eggplant) in hot water for 6 minutes, which were then cooled and pureed using a blender (Kenwood Multi Pro FP734 Food Processor). The puree was then mixed with sugar, milk, and cream, and the mixture churned in an ice cream maker (Cuisinart ICE-100 Compressor Ice Cream and Gelato Maker, Stamford, USA, Cuisinart). Samples were served using polystyrene cups, where they remained refrigerated (~4ºC) until served. A scoop of gelato sample (5.0 ± 0.8 g) was placed individually into a sealed 15 mL white plastic container (45 mm diameter) coded with a three-digit random number. The samples were stored in a commercial-grade freezer (Fisher and Paykel, NZ) at -18°C for at less 24 h prior to testing to ensure sample consistency. All samples were tempered for one minute at room temperature prior to serving. The serving temperature (−12 ± 2°C) was strictly monitored to maintain consistency across samples and panellists (Bower & Baxter, 2003). Sample presentation was randomized and counterbalanced across panellists (MacFie et al., 1989). Participants were given a 30 second break in between samples and instructed to drink water to cleanse their palate.

2.2 Ethics statement

Ethical approval by the Auckland University of Technology Ethics Committee (AUTEC 17/202) was obtained for this study. Participants were provided with informed consent forms prior to the commencement of the study and were rewarded with supermarket vouchers for their participation in the experiment.

2.3 Participants

Participants were recruited online through advertisements posted on social networking services (Facebook (Cambridge, Massachusetts, Meta Platforms, Inc.), and Instagram, (San Francisco, Meta Platforms) (formerly Facebook, Inc.)). None of the panellists were smokers, and none reported hearing loss, eating disorders, or other health problems associated with food. Fifty-seven participants (36 female, 21 males) ranging from 18 to 50 years old (M_{age} =25 years; SD = 4.75 years) took part in the chocolate milkshake study. Sixty-five participants (39 females, 26 males) aged between 20 and 40 years old (M_{age} = 32 years; SD = 5.63 years) were recruited for the vegetable ice cream study. Both the sensory testing of chocolate milkshake and vegetable ice cream were carried out at the purpose-built Auckland University of Technology sensory laboratory.

2.4 Sound selection

A preliminary study was carried out to select fourteen sounds that best represented pleasant and unpleasant sounds. Twenty sounds were presented to fifty-four participants (33 females, 21 males) ranging from 21 to 60 years old. Participants rated the pleasantness of the sounds using an unstructured line scale (0 as the most unpleasant; 5 as neutral; 10 as the most pleasant). Seven pleasant ($M_{pleasantness}$ = 7.61; *SD* = 1.77) and unpleasant sounds ($M_{pleasantness}$ = 2.22; *SD* = 1.72) were categorised. Individually, the seven pleasant sounds (PS) had mean ratings between 7.71 (*SD* = 1.46) and 9.13 (*SD* =0.81). The seven unpleasant sounds had mean ratings between 1.09 (*SD* =0.82) and 2.62 (*SD* =1.80).

The sounds that best represented pleasant and unpleasant sounds (see Appendix 3) used in this study were purchased from Soundsnap (https://www.soundsnap.com/, Nicosia, Cyprus, SOUNDSNAP Trademark of OJOO Limited) and downloaded from SoundCloud (https://soundcloud.com/, Stockholm, Sweden, SoundCloud Limited). Panellists rated the pleasantness of 14 different sounds using an unstructured line scale (0 as the most unpleasant; 5 as neutral; 10 as the most pleasant). Then the most pleasant and unpleasant sound conditions were identified for each individual panellist. During the experiment the selected sounds were played to each participant over a pair of Sennheiser Series HD 518 headphones (Sennheiser Electronics GmbH and Co. KG, Wademark, Germany) using a standard PC sound card. The order in which the various auditory stimuli were delivered was randomized and counterbalanced to minimize any order effects. All sounds were high-pass filtered using Adobe Audition 3.0 (Adobe, San Jose, CA, USA) to balance sound pressure levels across all sound samples. The Root Mean Square amplitudes of the audio samples were standardized to an internal reference to achieve equivalent average sound pressure levels across all audio samples, and later scaled to 70 dB sound pressure level using a Brüel and Kjær sound meter (Brüel & Kjær, Nærum, Denmark).

2.5 Temporal dominance of sensation (TDS)

The TDS method used in the study was carried out according to Pineau, Cordelle, Imbert, Rofeaux, & Schlich (2003). TDS is a technique which can record several sensory attributes concurrently across time (Pineau et al., 2009). In the chocolate milkshake study, changes in cocoa, sweetness, milky, creamy, and thickness (see Table 1) while listening to pleasant and unpleasant environmental sounds was investigated using the TDS method. In the vegetable ice cream study, changes in sweet, milky, creamy, vegetable, grassy, and earthy (see Table 1) attributes while listening to the pleasant and unpleasant environmental sounds was investigated using TDS (see Appendix 4). TDS data was binary coded across time (0 for an unselected attribute and 1 for selected attribute). If one button representing a single sensory attribute was selected, then the other buttons would automatically become deselected in order to adhere to the concept of dominance. The FIZZ Acquisition software (v. 2.46b: Biosystemes, France) was used to acquire the sensory data.

2.5.1 Chocolate milkshake and vegetable ice cream attribute selection

Attribute selection for both the chocolate milkshake and vegetable ice cream was carried out separately using 56 participants (33 female, 23 males) ranging from 18 to 50 years old (M_{age} = 29 years; *SD* = 6.66 years). For vocabulary development, the participants were requested to write down all the sensory attributes perceived when consuming the samples (Kantono et al., 2018). A total of 33 attributes were generated for the milkshake samples. The highly cited attributes of cocoa, sweetness, milky, creamy, and thickness were chosen for the TDS procedure. A total of 30 attributes was generated for the vegetable ice cream samples. The highly cited attributes of sweet, milky, creamy, vegetable, grassy, and earthy were chosen for the TDS procedure.

Table 1. Sensory attributes and descriptions of chocolate milkshake and vegetable ice cream.

Sensory attributes	Description	Reference standard
Chocolate milkshake		
Sweet (taste)	Taste quality most often associated with sucrose	Hershey Milk chocolate
Cocoa (flavour)	The flavour of cocoa	Hershey Milk chocolate
Milky (flavour)	The flavour of sweetened condensed milk and/or evaporated milk	Fresh milk (Anchor™, New Zealand)
Creamy (texture)	In-mouth sensation of smooth, thick texture and moderate melting rate	Fresh cream (Anchor™, New Zealand)
Thickness (texture)	Resistance to flow in mouth	Vanilla custard (Anchor™, New Zealand)
Vegetable ice cream		
Vegetable (flavour)	Taste characteristics of vegetable	Boiled and ground vegetable (asparagus and eggplant)
Grassy (flavour)	Aromatics associated with freshly cut grass	Cis-3-hexenol (5 μL in 100 mL water)
Earthy (flavour)	Somewhat sweet, heavy aromas associated with decaying vegetation and damp black soil	Sliced raw button mushrooms
Sweet (taste)	Taste elicited by, for example, sucrose of other sugars	10% w/w, sucrose solution, 8°C
Milky (flavour)	The flavour of cooked cow's milk	Fresh milk (Anchor™, New Zealand), 8°C
Creamy (texture)	The flavour of high-fat fresh cream.	Fresh cream (Anchor™, New Zealand), 8°C

2.5.2 Panel training

Panel training was carried out over three sessions for a total of 10 h. Panellists were informed that they would be listening to different sounds while consuming chocolate milkshake or vegetable ice cream. In the first training session, panellists familiarized themselves with the measurement of flavour sensations using the TDS procedure. They were introduced to the concept and to the measurement of dominance. 'Dominance' of attributes was defined as the attribute that most captures your attention at a given time. The panellists were informed that the dominance of a sensory attribute might change if a new sensory attribute became more salient (Labbe et al., 2009; Pineau et al., 2009). The panellists were required to select the dominant attribute, for example sweetness, when present. A dummy TDS trial was carried out in the second training session using samples of chocolate milkshake or vegetable ice cream under silence. In the third session, panellists carried out simulated TDS trials on samples of milkshake or ice cream while listening to 45 s of selected sounds. This allowed familiarization with the computer interface and TDS method. In the final training session, the panellists were acquainted with food-related emotional attributes scales and given both a definition and example of the events that might be associated with the emotion (Desmet & Schifferstein, 2008).

2.6 Emotional responses

2.6.1 The Self-Assessment Manikin (SAM)

The SAM was used in this study to measure valence, arousal, and dominance (Bradley & Lang, 1994). The participants were presented with an unstructured line scale with a continuous line scale for the attributes of valence, arousal, and dominance (Lang, 1980), and these measurements were used to determine the panels' affective responses towards the sound stimuli when consuming ice cream (Kantono et. al., 2016). Valence was described as the pleasantness (from unpleasant to pleasant) of the sample. Arousal was described as the intensity of emotion evoked by the sample (from calm to excited), and dominance was described as the extent to which the sample grabs one’s attention (from controlling to not controlling attention).

2.6.2 Measurement of emotions using check-all-that-apply (CATA)

A preliminary study was carried out using a focus group consisting of 36 participants (16 males, 20 females) between 21 and 34 years of age to capture the emotions experienced during consumption of ice cream under the two different sound conditions. In this study, emotional terms without reference to food or sound were selected from the Profile of Mood States (McNair, Droppleman, & Lorr, 1971), Multiple Affect Adjective Check List Revised (Lubin & Zuckerman, 1999), Positive and Negative Affect Scale (Watson, Clark, & Tellegen, 1988), and the Geneva Affect Label Coder (Scherer, 2005). Out of an initial 150 terms, the twenty-most relevant and well understood emotional terms were selected by panellists.

The CATA approach consisted of a list of 20 emotional attributes. There were ten positive emotional terms (active, at ease, calm, energetic, enthusiastic, excited, interested, joy, pleasant, and relaxed), nine negative emotional terms (annoyed, anxious, boredom, lonely, restless, tired, unable to concentrate, uneasy, and unhappy), and a single neutral emotional term (satisfaction). The consumers were instructed to indicate all the terms from the list that they considered appropriate to characterising emotional responses after tasting the chocolate ice cream samples while listening to the different sounds. Emotion-related CATA questions have been used in studies of chocolate ice cream previously (Kantono et al., 2016, 2018, 2019; Xu et al., 2019a, b). The presentation order of the CATA terms of the emotions were balanced between- and within-participants following a Williams' Latin square experimental design (Ares, Antúnez, Giménez, & Jaeger, 2015b). The participants had to indicate all of the terms that they considered appropriate to describe their emotions when evaluating each ice cream sample under different sound conditions using the FIZZ Sensory Analysis Software (Biosystèmes, France).

2.7 Data analysis

All univariate and multivariate analyses in this study were carried out using XLSTAT 2020.1.1 (Addinsoft, Long Island City, NY, USA).

2.7.1 Psychoacoustic analysis of sounds

In psychoacoustic analysis, parameters other than sound pressure level are needed to fully characterise a sound. These parameters included tonality, fluctuation strength, roughness, and sharpness, all of which co-vary with human responses to sound. According to Fastl and Zwicker (2007, pp. 111-148), tonality provides a measure of the relative content of pure tones in a sound, with white noise being an example of a sound low in tonality. Fluctuation strength provides a measure of amplitude modulation; that is, cyclic variations in amplitude, and roughness is a measure of modulation with lower frequencies (15–300 Hz). Sharpness provides a measure of the relative content of high frequencies in a signal. In the current study, these psychoacoustical parameters were calculated using the National Instruments LabVIEW 2013 software (National Instruments, Austin, TX, USA).

2.7.2 Temporal dominance of sensation (TDS) curves

In this study, TDS dominance curves were used to exhibit the dominance ratings of all sensory attributes over time by using the in-built spline-based smoothing algorithm (Ng et al., 2012) resident in the FIZZ software (Pineau et al., 2009). Temporal dominance curves displayed the percentage of panellists who recognised the prescribed attributes as being dominant at a given time (Pineau et al., 2009).

The TDS time period is presented as standardized time (ST), and data was converted to percentages (0–100%: Ares et al., 2015). For each participant, time data was standardized to a score between 0 and 100, where 0 was when they first clicked on the line scale, and 100 was when they clicked stop or when the recording stopped automatically. The calculation of the significant (P_s) and the chance (P_0) levels was carried out according to Pineau et al. (2009). Spline-based smoothing was applied on each curve.

2.7.3 One-way analysis of variance (ANOVA) of affective responses

A one-way ANOVA was performed on the valence (hereby called pleasantness), arousal, and dominance measures as a function of the different auditory conditions. *Post hoc* comparison using Tukey's (HSD) was applied if statistical significance was observed ($p < 0.05$).

2.7.4 Multidimensional Alignment (MDA)

Multidimensional Alignment (MDA) is often used to analyse CATA data (Carr et al., 2009, Meyners et al., 2013), and in this study MDA was applied to determine the cosine values between the auditory conditions and emotion attributes. By calculating the cosine of the angle (range −1 to 1) formed between each attribute and condition, it is possible to determine the relationship between conditions and attributes. Absolute cosines below 0.707 indicate hardly any relationship at all (Carr et al., 2009).

2.7.5 Canonical Variate Analysis (CVA)

CVA was performed on perceptual and emotion data. CVA minimizes residual variability and maximizes the distances between samples (Delarue & Sieffermann, 2004). Additionally, Hotelling Lawley Analysis of Variance (MANOVA) tests were used to determine whether significant differences existed between the seven different sound conditions in terms of the standardized durations of flavour ($p < 0.05$).

2.7.6 Multiple Factor Analysis (MFA)

Multiple Factor Analysis (MFA) enables the simultaneous analysis of datasets of variables to study the relationship between the observations and variables (Escofier & Pages, 1994). In this study, MFA was applied to the TDS sensory duration and emotional measures across all samples and conditions. This allowed the relationship between the sensory responses and emotional measurements when food was consumed under different sound conditions to be examined.

3. Results

3.1 Psychoacoustic Parameters

The results for the different sound conditions are presented in Appendices 6A and 6B. The sharpness, roughness, and fluctuation strength of pleasant sounds were higher than unpleasant sounds. Shu and Ma (2018) reported that high restorative values of environmental sounds were positively correlated with fluctuation strength and sharpness. Meanwhile, Hall et al. (2013) found that sharpness, roughness, and loudness were significant predictors of pleasant urban soundscapes. An important finding from the present study is that urban sounds such as outdoor restaurant dining, traffic, airport, indoor marketplace, bar, and fast food restaurant background sounds (see Appendix 3) were judged to be unpleasant. Hall et al. (2013) reported that urban soundscapes dominated by machine or traffic noise tended to be viewed as being more unpleasant than other natural environments or settings reflecting human activity.

3.2 Temporal dominance of Sensation (TDS)

3.2.1 Perceptions of chocolate milkshake (CM) with different sound conditions.

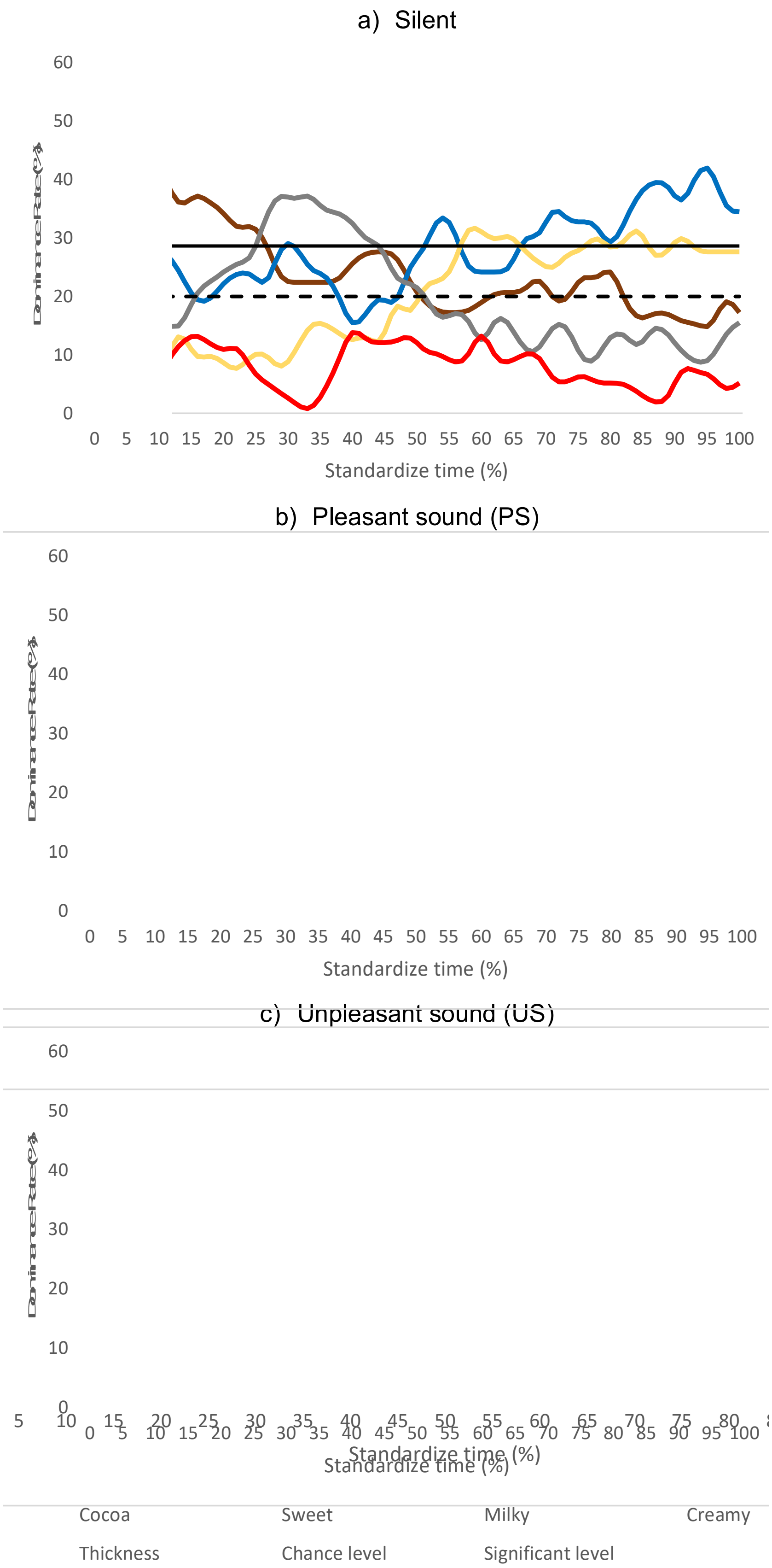

Figure 1. TDS dominance curves for chocolate milkshake consumed under: (a) silent; (b) PS; (c) US conditions. Panel dominance rates (%) of the five sensory attributes presented in the TDS sessions are expressed as % standardized time.

Figure 1 shows the spline smoothed TDS dominance curves describing the dominance rate of various chocolate milkshake attributes when consumed in the silent and the various different sound conditions. The calculated chance and significant levels were between 20.00% and 28.64%, respectively. Only changes in attributes above 28.7% (see significance level) will be explained and discussed in this study.

Silent condition (S)

For the silent condition (see Figure 1 (a)), cocoa increased from 0% to 9% standardized time (ST), reaching a highest maximum dominance rate of 42.83% under the PS condition compared to the US condition, and then decreasing to 25% ST. Sweetness then increased from 52% ST, reaching a maximum dominance rate of 33.43% at 54% ST, and then decreased to 56% ST. Sweetness further increased from 67% ST, reaching a maximum dominance rate of 41.93% at 95% ST, and then decreased through to 100% ST. Creaminess increased from 26% ST, reaching a maximum dominance rate of 37.14% at 33% ST, and then decreased to 44% ST. Milky increased from 57% ST, reaching a maximum dominance rate of 31.65% at 59% ST, and then decreased to 66% ST.

Pleasant sound (PS) condition

While listening to PS (see Figure 1 (b)), sweetness reached the highest maximum dominance rate of 53.45% at the start of consumption compared to the silent and US conditions, and decreased until 4% ST. Sweetness then increased from 22% ST, reaching a maximum dominance rate of 34.32% at 28% ST, and then decreased to 32% ST. Sweetness had the longest duration under the PS condition compared to the silent and US conditions, increasing from 40% ST, reaching a maximum dominance rate of 48.09% at 88% ST, and then decreasing through to 100% ST. Cocoa increased from 5% ST, reaching a maximum dominance rate of 37.39% at 5% ST, and then decreased to 8% ST.

Unpleasant sound (US) condition

In the US condition (see Figure 1 (c)), sweetness was dominant at the start of consumption, with a maximum dominance rate of 43.10% at 0% ST that then decreased until 19%. Sweetness then increased from 50% ST, reaching a maximum dominance rate of 39.62% at 53% ST, and then decreased to 80% ST. Cocoa had the longest duration under US condition compared to silent and PS conditions. It increased from 23% ST, reaching a maximum dominance rate of 42.90% at 40% ST, and then decreased to 49% ST. A long duration of milky was evident under US condition compared to silent and PS conditions. It increased from 81% ST, reaching a maximum dominance rate of 34.30% at 90% ST, and then decreased to 93% ST.

3.2.2 Changes in sensory perception of vegetable ice cream while listening to different sounds

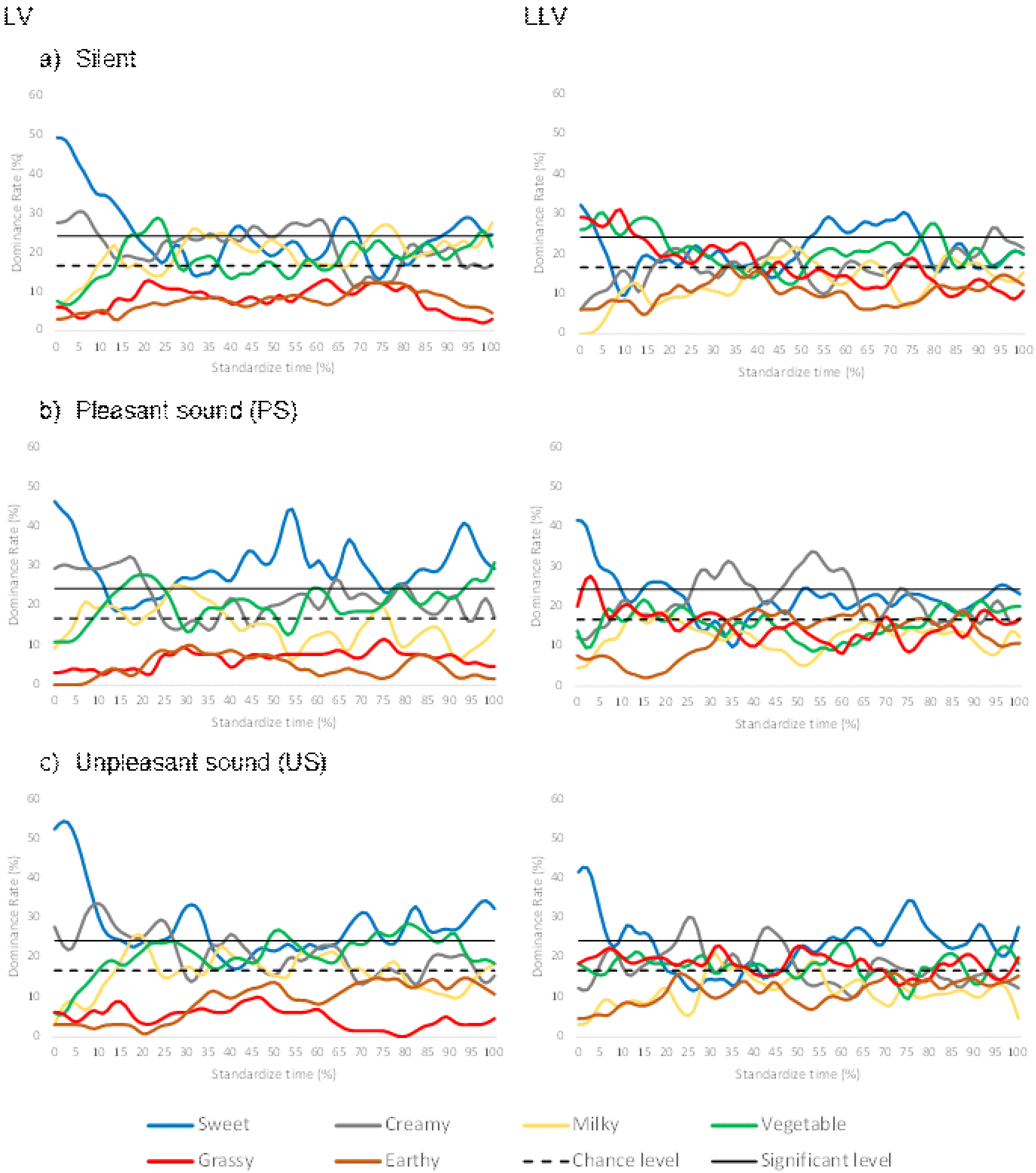

Figure 2. TDS dominance curves for liked (LV) and less liked (LLV) vegetable ice creams consumed under: (a) silent; (b) PS; and (c) US conditions. Panel dominance rates (%) of the six sensory attributes presented in the TDS sessions are expressed as % of standardized time. The calculated chance and significance levels were 16.67% and 24.27%, respectively.

3.2.2.1 Consumption of Liked Vegetable Ice Cream (LV) in Silent Condition

As seen in Figure 2 (a), sweetness was dominant with a maximum dominance rate of 49.23% when consumption commenced in the silent condition, that decreased in dominance until 17% ST. Sweetness increased from 64% ST, reaching a maximum dominance rate of 29.01% at 66% ST, and then decreased until 69% ST. Sweetness also increased from 89% ST, reaching a maximum dominance rate of 29.03% at 94% ST, and then decreased until 98% ST. A higher dominance rate of sweet was evident when consuming LV (highest maximum dominance rate of 49.23%) compared to LLV. A long duration of vegetable was evident from 18% ST, reaching a higher maximum dominance rate of 28.94% at 23% ST, and then decreased until 25% ST under the silent condition compared to PS and US conditions. A long duration of creaminess was also evident from 44% ST, reaching a maximum dominance rate of 28.46% at 60% ST, and then decreasing to 62% ST under silent condition compared to PS and US conditions. Milky increased from 73% ST, reaching a maximum dominance rate of 27.11% at 76% ST, and then decreasing until 77% ST. Milky also increased from 99% ST, reaching a maximum dominance rate of 27.69% at 100% ST.

3.2.2.2 Consumption Less Liked Vegetable Ice Cream (LLV) in Silent Condition

As can be seen in Figure 2 (a), sweetness was dominant with a maximum dominance rate of 32.31% at the start of consumption in the silent condition that then decreased until 2% ST. A long duration of sweetness was evident increased from 52% ST, reaching a maximum dominance rate of 30.51% at 73% ST, and then decreased until 76% ST when consumed LLV compared to LV in silent condition. Grassy increased from 7% ST, reaching a maximum dominance rate of 31.17% at 9% ST, and then decreased until 10% ST. Vegetable increased from 3% ST, reaching a higher maximum dominance rate of 30.40% at 5% ST, and then decreased until 6% when consumed LLV compared to LV in silent condition. Vegetable increased from 11% ST, reaching a maximum dominance rate of 29.13% at 14% ST, and then decreased until 18%. Vegetable then increased from 77% ST, reaching a maximum dominance rate of 27.69% at 80% ST, and then decreased until 81% ST.

3.2.2.3 Consumption Liked Vegetable Ice Cream (LV) in PS Condition

As seen in Figure 2 (b), sweetness was dominant with a maximum dominance rate of 46.15% at the start of consumption in the PS condition that then decreased until 9% ST. A long duration of sweetness was perceived under the PS condition compared to silent and US conditions, increasing from 28% ST, reaching a maximum dominance rate of 44.20% at 54% ST, and then decreasing until 99% ST. A longer ST and higher dominance rate of sweetness was evident when consuming LV (with a maximum dominance rate of 46.15%) compared to LLV under PS condition. Creaminess was the next dominant attribute from 9% ST, reaching a maximum dominance rate of 32.29% at 17% ST, and then decreased until 19% ST. Vegetable increased from 19.5% ST, reaching a maximum dominance rate of 29% at 20% ST, and then decreased until 24% ST. Vegetable also increased from 99% ST, reaching a maximum dominance rate of 30.77% at 100% ST, under PS condition.

3.2.2.4 Consumption Less Liked Vegetable Ice Cream (LLV) in the PS Condition

As seen in Figure 2 (b), sweetness was only dominant at the start of consumption in the PS condition, with a maximum dominance rate of 41.54% at 0% ST that then decreased until 9% ST. Creaminess was the next dominant attribute from 26% ST, reaching a maximum dominance rate of 31.29% at 34% ST, and then decreased until 40% ST. Creamy increased from 47% ST, reaching a higher maximum dominance rate of 33.74% at 53%, and then decreased until 62% ST when consumed LLV compared to LV in PS condition. A long duration of creaminess was perceived under PS condition compared to silent and US conditions.

3.2.2.5 Consumption of Liked Vegetable Ice Cream (LV) in the US Condition

As seen in Figure 2 (c), sweetness was dominant at the start of consumption in the US condition, with the highest maximum dominance rate of 54.32% compared to the silent and PS conditions that then decreased until 9% ST. A higher dominance rate of sweetness was evident when consuming LV (highest maximum dominance rate of 54.32%) compared to the LLV under US condition. Sweetness increased from 27% ST, reaching a maximum dominance rate of 33.33% at 31% ST, and then decreased until 35% ST. Sweetness then increased from 65% ST, reaching a maximum dominance rate of 31.35% at 70% ST, and then decreased until 73% ST. Sweetness further increased from 80% ST, reaching a maximum dominance rate of 34.32% at 98% ST, and then decreased until 100% ST. Creaminess was the next dominant attribute from 10% ST, reaching a higher maximum dominance rate of 33.65% at 10% ST, under US condition that then decreased until 26% when consumed LV compared to LLV in US condition. A longer ST of creaminess was evident when consuming LV compared to LLV under US condition. A higher dominance rate of creaminess was evident when consuming LV (highest maximum dominance rate of 33.65%) under US condition compared to silent and PS conditions. Vegetable increased from 74% ST, reaching a maximum dominance rate of 27.74% at 79% ST.

3.2.2.6 Consuming Less Liked Vegetable Ice Cream (LLV) in the US Condition

As can be seen in Figure 2 (c), sweetness of LLV increased at 0% ST in the US condition, reaching a higher maximum dominance rate of 42.71% at 1% ST, compared to silent and PS conditions that then decreased until 16% ST. A long duration of sweetness was evident under the US condition compared to silent and PS conditions. Sweetness increased from 57% ST, reaching a maximum dominance rate of 34.42% at 75% ST, and then decreased until 82% ST. Sweetness then increased from 89% ST, reaching a maximum dominance rate of 28.39% at 91% ST, and then decreased until 100% ST. Creaminess was the next dominant attribute from 23% ST, reaching a higher maximum dominance rate of 30.19% at 25% ST compared to silent and PS conditions, and then decreased until 27% ST.

3.3 Affective dimensions

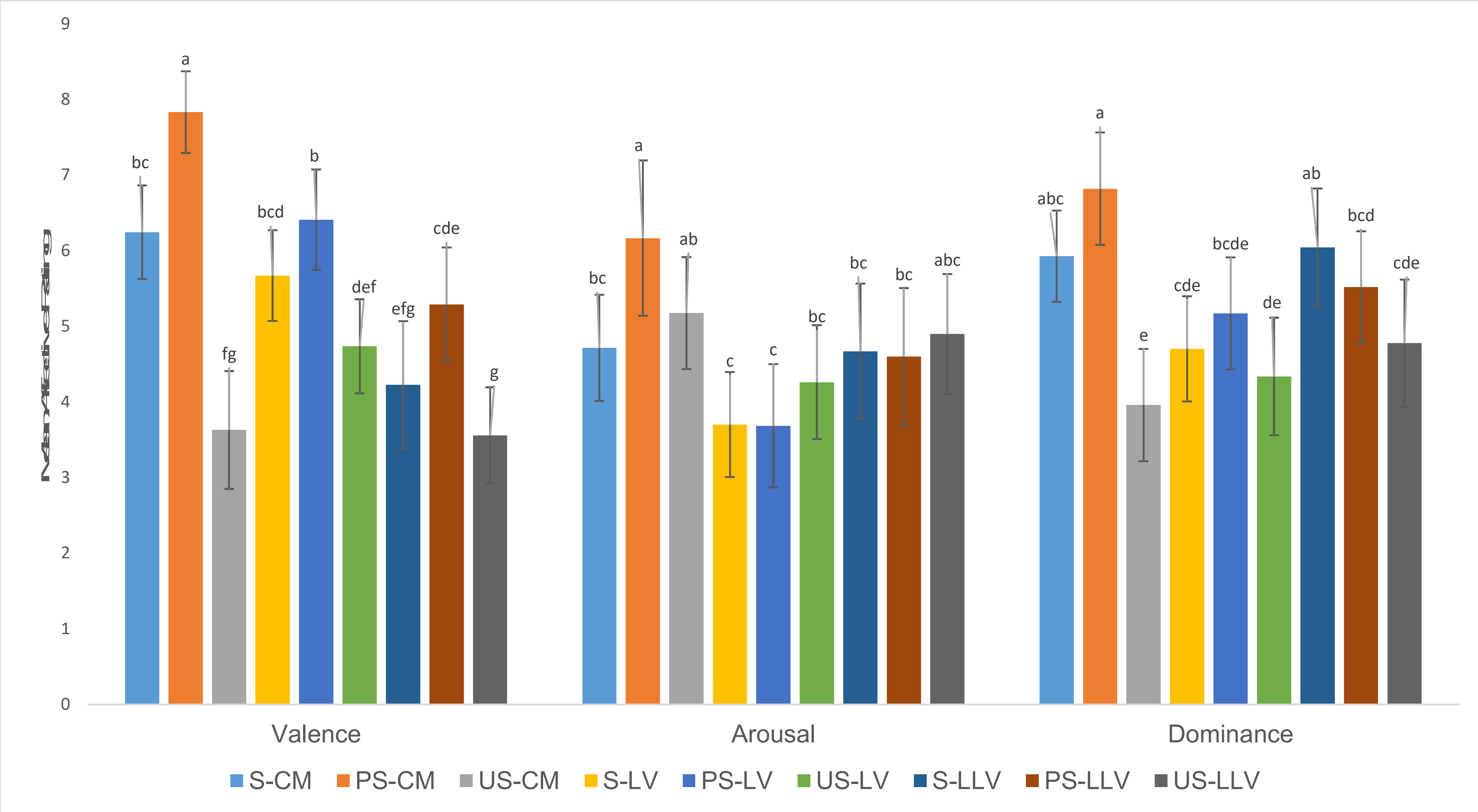

Figure 3. Differences in valence, arousal, and dominance during consumption of chocolate milkshake (CM), as well as liked and less liked vegetable ice cream (LV and LLV) under sound conditions varying in pleasantness. The sound conditions included silent, pleasant sound (PS),

and unpleasant sound (US) conditions. Mean affective ratings of sound conditions with different small letters (a-g) indicate significant differences in affective ratings. Error bars indicate the standard error.

3.3.1 Changes in affective dimensions with sounds varying in pleasantness after consumption of chocolate milkshake and vegetable ice cream

As seen in Figure 3, affective dimensions associated with the consumption of foods (CM, LV and LLV) was influenced with sound conditions varying in pleasantness. There were significant differences in terms of valence ($F_{(72,\ 560)}$ = 5.10, p < 0.001, partial eta squared = 0.43), arousal ($F_{(72,\ 560)}$ = 2.01, p < 0.001, partial eta squared = 0.23), and dominance ($F_{(72,\ 560)}$ = 2.37, p < 0.001, partial eta squared = 0.26). CM had the highest affective ratings in valence, followed by LV and LLV while listening to the pleasant sound (PS). CM had significantly higher ratings in arousal and dominance compared to LV and LLV under PS condition. Only LV had significantly higher valence than CM and LLV for the US condition. There were no significant differences between CM, LV and LLV in terms of arousal and dominance under the US condition.

3.4 Multidimensional Alignment (MDA)

	S_CM	PS_CM	US_CM	S_LV	PS_LV	US_LV	S_LLV	PS_LLV	US_LLV
Pleasant (+)	0.928	0.904	-0.793	0.602	0.792	-0.793	-0.280	0.457	-0.918
Interested (+)	0.250	0.377	-0.669	0.567	0.527	-0.426	0.588	0.555	-0.629
Joy (+)	0.808	0.920	-0.800	0.574	0.862	-0.870	-0.229	0.620	-0.905
Relaxed (+)	0.714	0.533	-0.781	0.806	0.973	-0.755	-0.333	0.824	-0.820
Active (+)	0.301	0.787	-0.505	-0.004	0.155	-0.467	0.418	0.191	-0.426
Calm (+)	0.743	0.329	-0.767	0.856	0.847	-0.667	-0.192	0.791	-0.738
Satisfied (+)	0.720	0.916	-0.764	0.611	0.814	-0.834	-0.157	0.465	-0.866
Enthusiastic (+)	0.359	0.648	-0.538	-0.151	0.390	-0.218	0.074	0.539	-0.524
Energetic (+)	0.308	0.671	-0.458	-0.090	0.121	-0.422	0.461	0.440	-0.452
At ease (+)	0.966	0.558	-0.640	0.677	0.693	-0.613	-0.494	0.371	-0.764
Unable to concentrate (-)	-0.746	-0.710	0.976	-0.719	-0.812	0.699	-0.115	-0.701	0.861
Annoyed (-)	-0.817	-0.782	0.708	-0.712	-0.826	0.872	0.069	-0.568	0.975
Restless (-)	-0.850	-0.762	0.924	-0.760	-0.882	0.848	0.106	-0.776	0.912
Tired (-)	-0.775	-0.788	0.977	-0.511	-0.772	0.593	-0.022	-0.635	0.827
Uneasy (-)	-0.874	-0.813	0.949	-0.674	-0.878	0.750	0.231	-0.672	0.878
Unhappy (-)	-0.879	-0.757	0.677	-0.602	-0.818	0.773	0.626	-0.475	0.754
Anxious (-)	-0.864	-0.753	0.729	-0.755	-0.879	0.835	0.215	-0.596	0.983
Boredom (-)	-0.754	-0.872	0.672	-0.314	-0.745	0.592	0.289	-0.491	0.862
Lonely (-)	-0.374	-0.535	0.077	-0.259	-0.246	0.791	0.040	-0.303	0.460
Excited (+)	0.104	0.397	-0.242	-0.458	-0.163	0.209	0.455	-0.107	-0.159

Table 2. Cosine values between sound conditions (silent, S; pleasant sound, PS, and unpleasant sound, US conditions) with different food samples (chocolate milkshake, CM; liked vegetable ice cream, LV; and less liked vegetable ice cream, LLV) and the emotion attributes obtained by Correspondence Analysis (CA). Values in green and red indicate high positive and negative correlations respectively between the emotions attribute and food samples, consumed under different sound conditions.

3.4.1 Emotions elicited after consuming different types of foods under varying sound conditions

Multidimensional alignment (MDA) was applied to determine the cosine values between the sound conditions and emotions cited when consuming chocolate milkshake and vegetable ice cream. Table 2 highlights the emotions that are positively and negatively correlated with the varying sound conditions using the first two dimensions of the CA bi-dimensional map. Cosine values greater than 0.707 (Carr et al., 2009) suggest a strong relationship between sound conditions and the emotion attributes.

For the chocolate milkshake, the silent condition was positively correlated with the positive emotions of pleasant, joy, relaxed, calm, satisfied, and at ease. The PS condition was positively correlated with the positive emotions of pleasant, joy, active, and satisfied. The US condition was positively correlated with the negative emotions of unable to concentrate, annoyed, restless, tired, uneasy, and anxious.

With liked vegetable (LV) ice cream, the silent condition was positively correlated with positive emotions of relaxed and calm. Consuming LV under PS condition was positively correlated with positive emotions of pleasant, joy, relax, calm, and satisfied. However, under the US condition there were positive correlations with negative emotions of annoyed, restless, uneasy, unhappy, anxious, and lonely. When consuming less liked vegetable (LLV) ice cream, the PS condition was positively correlated with positive emotions of relaxed and calm. Under the US condition, LLV was positively correlated with negative emotions of unable to concentrate, annoyed, restless, tired, uneasy, unhappy, anxious, and boredom.

3.5 Canonical Variate Analysis (CVA) of sensory and emotional responses to chocolate milkshake coinciding with different sound conditions

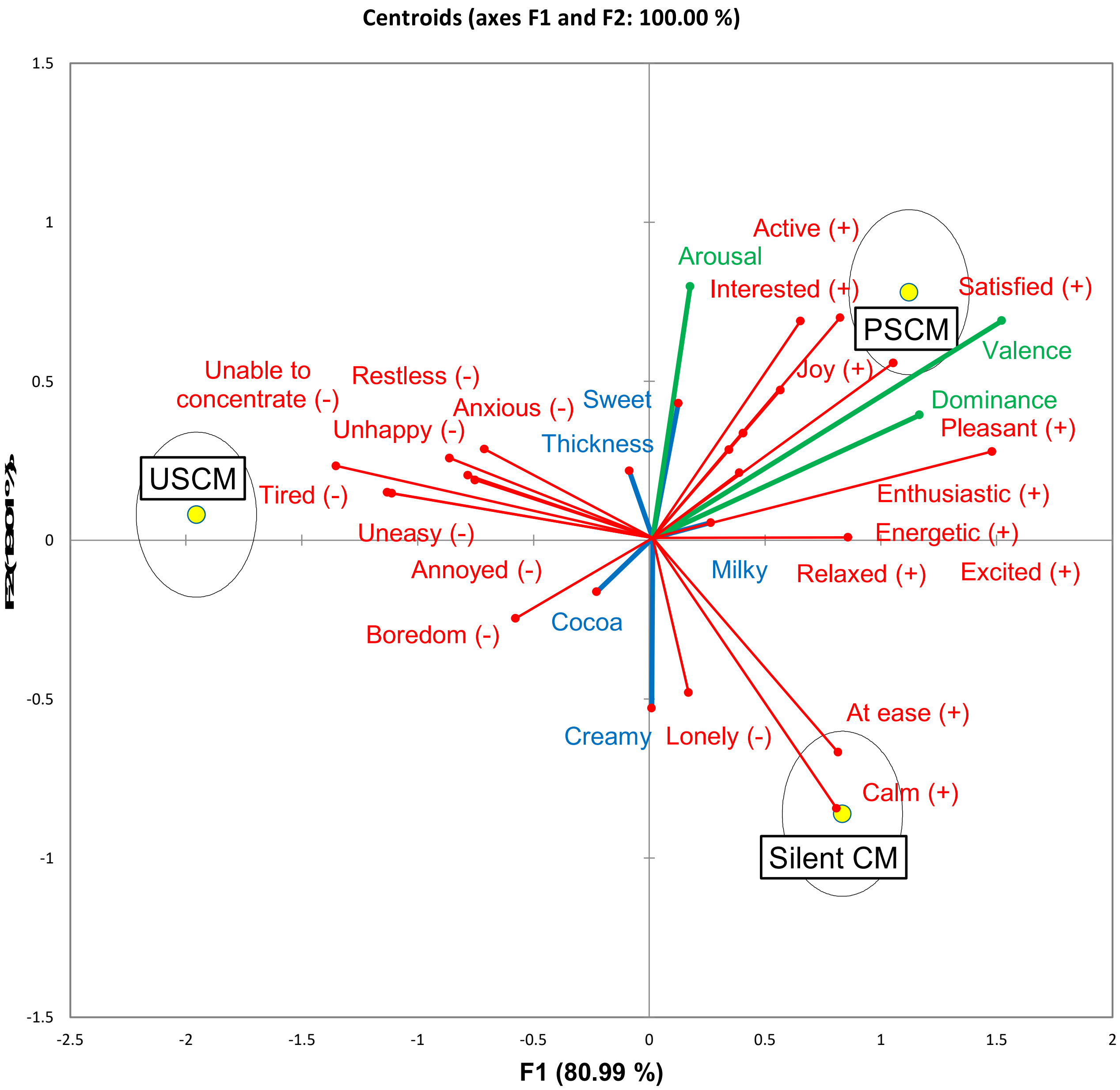

Figure 4. Joint Canonical Variate Analysis scores and loadings plots of dominance durations of sensations and emotional responses. A Hotelling-Lawley MANOVA test showed significant sample differences ($F_{(54,\ 260)} = 6.32$, $p < 0.0001$, partial eta squared = 0.57) based on sensory attributes and emotional responses. To aid visualization, emotional responses are labelled in red, affective measures are labelled in green, and sensory attributes are labelled in blue.

Canonical variate analysis (CVA) was used to further summarize the standardized duration of flavour perception when the chocolate milkshake (CM) was consumed under the different sound conditions (silent; pleasant sound (PS); and unpleasant sound (US)). Figure 4 describes the first two canonical variates, which explained 100% of the data. The Hotelling-Lawley MANOVA analysis results showed significant differences between the standardized duration of flavour perception of CM in the silent, PS, and US conditions ($F_{(54,\ 260)} = 6.32$, $p < 0.0001$, partial eta squared = 0.57). Along Factor 1 (F1) that explained 80.99% of the variance in the data, CM consumed under the PS condition had high positive scores along F1 that were correlated to the affective states of valence, and dominance, positive emotions of interested, active, satisfied, joy, pleasant, enthusiastic, energetic, relaxed, at ease, and calm, and the sensory attribute of sweetness and milky. Under the US condition, CM had a negative score along F1 that was correlated to the negative emotions of unable to concentration, restless, unhappy, anxious, tired, uneasy, annoyed, and boredom, and the perception of thickness and cocoa. The second factor (F2) accounted for 19.01% of the variance that further differentiated CM samples consumed under silent conditions. CM under the silent condition was correlated to perception of creaminess and the negative emotion of lonely.

3.6 Canonical Variate Analysis (CVA) of sensory and emotional responses to vegetable ice creams (LV and LLV) coinciding with different sound conditions

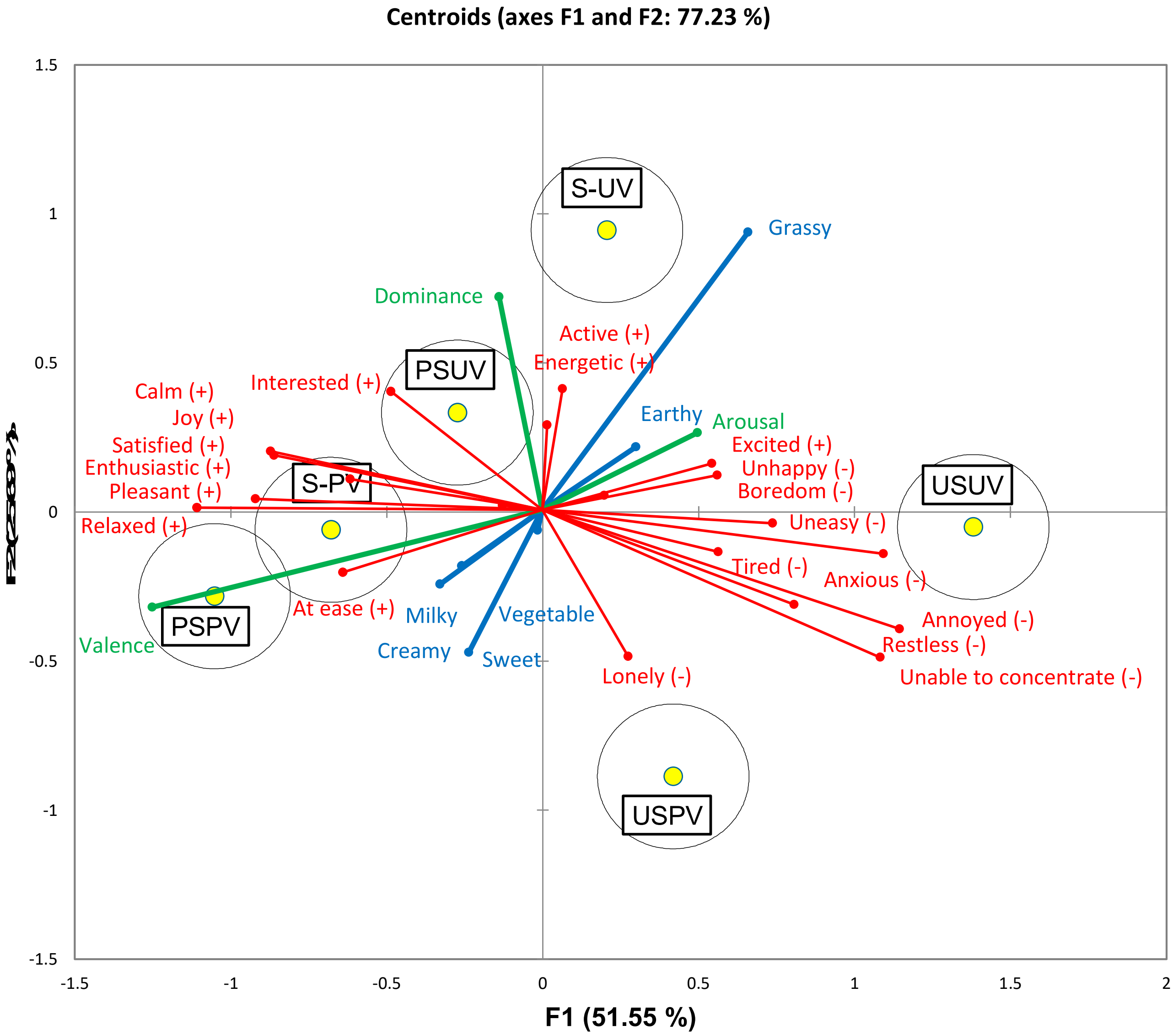

Figure 5. Joint Canonical Variate Analysis scores and loadings plots of dominance durations of sensations and emotional responses. To aid visualization, emotional responses are labelled in red, affective measures are labelled in green, and sensory attributes are labelled in blue.

Canonical variate analysis (CVA) was used to further summarize the standardized duration of the data when liked vegetable ice cream (LV) and less liked vegetable ice cream (LLV) were consumed under different sound conditions. Figure 5 describes the first two canonical variates, which explained 77.23% of the data. The Hotelling-Lawley MANOVA analysis results showed significant differences between the standardized duration of flavour perception of LV and LLV under silent, PS, and US conditions ($F_{(145, 1469)} = 3.03$, $p < 0.001$, partial eta squared = 0.23).

Figure 5 shows a clear separation of LV and LLV samples consumed under different sound conditions in terms of emotions and perceptions, with the first factor explaining 51.55% of the variance in the data separated LV and LLV conditions. For the US condition, LLV had high positive scores along F1 that were correlated with the affective states of arousal, negative emotions of unable to concentrate, annoyed, restless, tired, uneasy, unhappy, anxious, and boredom, and the perception of earthy. For the PS and silent conditions, LV had high negative scores along F1 that were correlated to the affective states of valence, positive emotions of pleasant, interested, joy, relaxed, calm, satisfied, and at ease, and perception of sweetness, creaminess, and milky.

The second factor (F2) accounted for 25.69% of the variance that further differentiated between LV under US condition and LLV under the silent condition. LLV under the silent condition had high positive scores along F2 that were correlated to the affective states of dominance, positive emotion of active, and perception of grassy. LV the under US condition had high negative scores along F2 and was correlated to the negative emotion of lonely.

3.7 Multiple Factor Analysis (MFA) of sensory and emotional responses to chocolate milkshake and vegetable ice creams (LV and LLV) coinciding with the different sound conditions

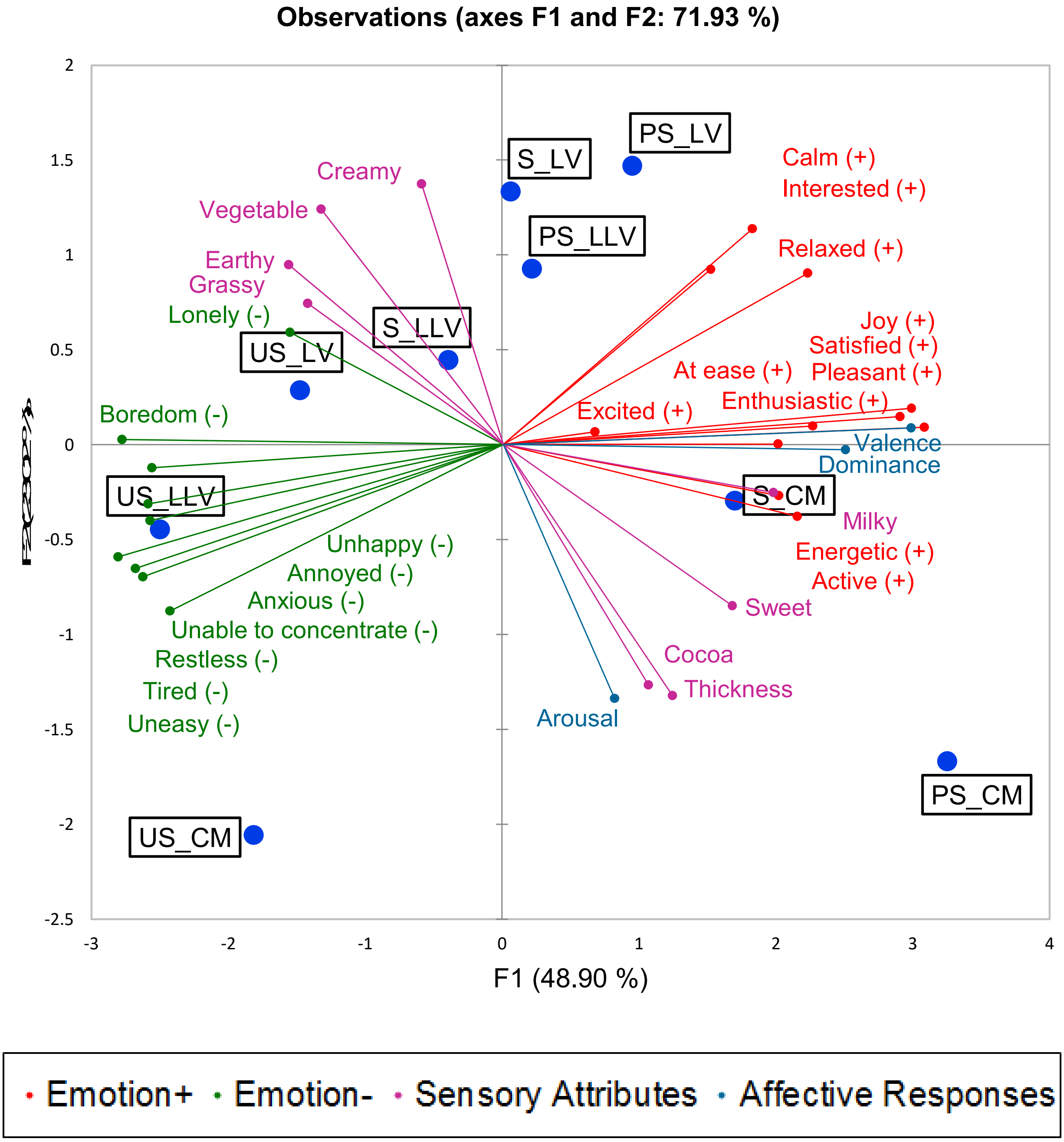

Figure 6. Multiple Factor Analysis (MFA) bi-plot for positive emotion (red), negative emotion (green), sensory attributes (pink), and affective responses (blue) for foods (chocolate milkshake, CM; liked vegetable ice cream, LV; less liked vegetable ice cream, LLV) consumed under varying in silent (S), pleasant sound (PS) and unpleasant sound (US) conditions.

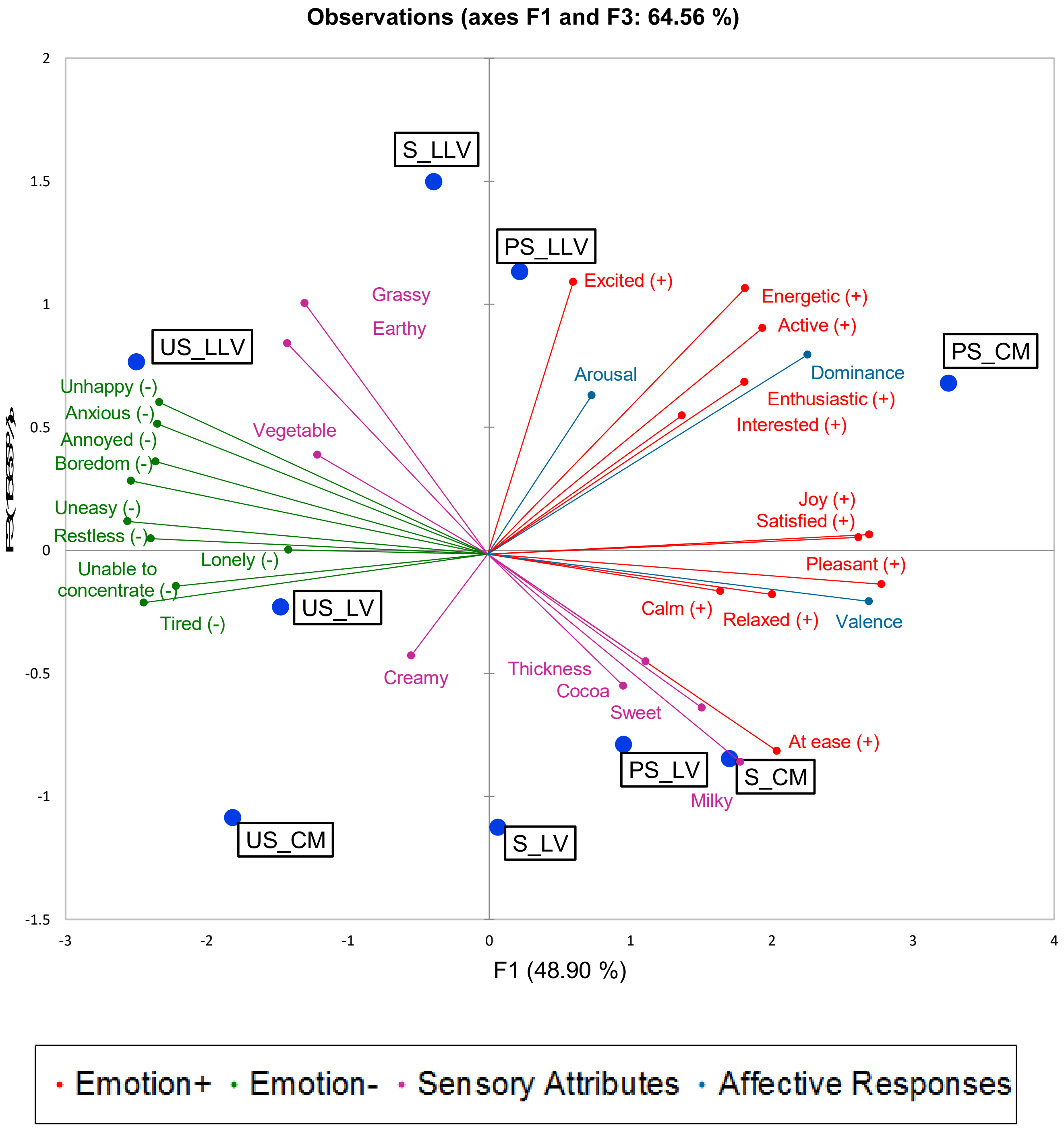

Figure 7. Multiple Factor Analysis (MFA) bi-plot for positive emotion (red), negative emotion (green), sensory attributes (pink), and affective responses that include valence (V), arousal (A) and dominance (D) (blue) for foods (chocolate milkshake, CM; liked vegetable ice cream, LV; less liked vegetable ice cream, LLV) consumed under silent (S) and pleasant sound (PS) and unpleasant (US) conditions.

Multiple Factor Analysis (MFA) makes it possible to analyse several tables of variables simultaneously, and to display the results in the form of charts that highlight the relationship between the observations, variables, and tables (Escofier & Pagès, 1984). Within a table, the variables must be of the same level of measurement (sensory attributes, emotions, and affective responses), but the tables can be of different types, in this case the different food samples. Figures 6 and 7 illustrate the MFA plots showing the interrelationship between emotion measures, affective responses, and sensation with varying pleasantness of sound (PS and US), and of different foods (CM, LV, LLV) for F1 (48.90%), F2 (23.02%), and F3 (15.65%) that explained a total of 87.58% of the variance.

The F1 axis explained 48.90% of the variance and differentiated the samples in terms of pleasant and unpleasant sound conditions. CM samples under PS and silent conditions had high positive scores along F1 that were correlated to perception of sweetness, milky, affective responses of valence and dominance, and positive emotions of pleasant, joy, relaxed, active, satisfied, enthusiastic, and at ease. LV and LLV samples consumed under the US condition had high negative scores along F1 that were correlated with the negative emotions of unable to concentrate, annoyed, restless, tired, uneasy, unhappy, anxious, boredom, and lonely.

Factor 2 (F2) explained 23.02% of the variability and further differentiated between LV and CM samples. The LV samples consumed under silent and PS conditions having high positive scores along F2 were associated with perception of creaminess, vegetable, earthy, and positive emotions of interested and calm. The CM sample under US condition having high negative scores along F2 were with thickness, cocoa, and arousal. F3 explained 15.65% of the variance and differentiated less liked and liked vegetable ice cream further. The LLV under the silent and pleasant sound conditions had positive scores along F3 that were associated with grass, and the positive emotions of energetic. The LV under silent condition had a negative score along F3 and were not associated with any sensory attributes and emotions.

4 Discussion

4.1 Chocolate milk evoked more emotions than the vegetable ice creams

We hypothesized that emotional food would evoke more emotions, while non-emotional foods would evoke less emotions. Our findings showed that a chocolate milkshake (i.e., an emotional food) elicited a greater emotional response as compared to vegetable ice creams (non-emotional foods) under conditions of silence. Several reports have shown how different types of food elicited different emotional responses. Desmet and Schifferstein (2008) reported sweet snacks had significantly higher mean emotion ratings for all positive emotions compared to a savoury snack and pasta meals. Similarly, Cardello et al. (2012) reported more positive emotional responses when eating chocolate (milk and dark) as compared to potato chips. Pelsmaeker et al. (2013) further found that chocolate milk exhibited the highest citation of positive emotions, while cow's milk had the highest citation of negative emotions. Similarly, Piqueras-Fiszman and Jaeger (2014) found that chocolate brownie showed significantly higher citations of emotions compared to a plain apple. All these studies show that those foods that contain chocolate elicit more emotions. In fact, Fiegel et al. (2014) reported milk chocolate as being an emotional food as it elicited more intense emotions when compared to bell pepper.

4.2 Liked vegetable ice cream evoked more emotions than less liked vegetable ice cream

Previous studies have shown that liked foods are associated with positive emotions (Samant & Seo, 2020), while disliked foods tend to be associated with negative emotions (Jaeger et al., 2014; Lagast et al., 2018; Schouteten et al., 2018; Waehrens et al., 2018). We hypothesized that liked foods would elicit a greater emotional response, while the foods that were less liked would have the opposite effect. The results of the present study confirmed that our participants made far more use of positive than negative emotional terms for the foods that are liked more. Chocolate milkshakes evoked more positive emotions than vegetable ice creams. In addition, liked vegetable ice cream (LV) evoked more positive emotions compared to less like vegetable ice cream (LLV). Interestingly, LLV evoked more negative emotions compared to LV and CM under the unpleasant sound (US) conditions, which has not been reported in any study to date.

In the current study, LV is more strongly associated with positive emotions, while LLV is more strongly associated with negative emotions. Similarly, Samant and Seo (2020) found that vegetable juices that were most liked had significantly higher mean ratings of “enthusiastic”, “good”, and “satisfied” after being consumed, while LLV juice only elicited significantly higher reports of disgust. Other studies demonstrate that liked foods such as chocolate sweetened with sugar and tagatose (Lagast et al., 2018), premium brand chocolate (Schouteten et al., 2018), commercially available breakfast drinks (Gutjar et al., 2015), strawberry beverages (Waehrens et al., 2018), and fruit chocolates (Jaeger et al., 2014) have all been shown to elicit more positive emotions than less liked foods.

4.3 Different emotions are elicited when consuming food under sound conditions varying in pleasantness

Studies show that significantly higher ratings of positive emotions are obtained while listening to liked music as compared to the silent, neutral music, and disliked music conditions while consuming chocolate ice cream (Kantono et al., 2016, 2018, 2019). On the other hand, negative emotions are rated significantly higher while listening to disliked music as compared to the silent, neutral music, and liked music conditions. Only a few studies have investigated how sounds varying in terms of pleasantness influence people's emotions while they are eating. The current study found that CM elicited the most intense positive emotions followed by LV and LLV during the pleasant sound conditions. This finding is in agreement with Xu et al. (2019a) who also demonstrated that positive emotions were significantly higher when listening to café-forest and café-bird soundscapes as compared to café-machine soundscapes during the consumption of chocolate ice cream. Medvedev, Shepherd, and Hautus (2015) reported that birdsong and ocean soundscapes were more pleasant than construction work and traffic soundscapes. Meanwhile, another study by Villarreal et al. (2012) found that water sound had the highest valence and liking, and lowest in arousal compared to control noise, and rain sound conditions. Therefore, reflecting on the findings of the current study, significantly higher ratings of positive emotions were evident when consuming CM, LV, and LLV while listening to pleasant sounds. On the other hand, significantly higher ratings of negative emotions were evoked when consuming LLV, LV, and CM while listening to unpleasant sounds.

4.4 Pleasantness of sound conditions influenced the dominant sensory attributes of foods

The present study found that the pleasantness of sound conditions influenced the selection of the dominant sensory attribute when consuming chocolate milkshake and vegetable ice creams. Chocolate has been described as an emotional food (Fiegel et al., 2014), and the findings of the present study confirmed that chocolate milkshake elicited more intense emotions than did vegetable ice creams. Sweetness was the most dominant attribute reported in chocolate milkshake, especially in the pleasant sound condition. The enhanced perception of sweetness under pleasant sound conditions has also been observed in other studies. Lin et al. (2019) reported that the sweetness of ice cream was most cited under highly pleasant sound conditions (café and park sounds). Kantono et al. (2016, 2018, 2019) further showed that sweetness was either dominant or highly cited when consuming chocolate ice cream when listening to liked music compared to disliked music.

Sounds varying in pleasantness can influence liked and less liked foods differently. In the present study, cocoa was dominant and perceived over a longer duration when consuming chocolate milkshake during the unpleasant as compared to the pleasant sound condition. This finding seemed to be consistent with findings reported by Lin et al. (2019). The latter researchers demonstrated that low valence food court soundscapes increased the mention of cocoa as compared to the other environmental sound conditions. Another important finding was that LV was more dominant in sweetness than LLV when consumed under the PS condition. This finding is consistent with those of Carvalho et al. (2017), who also found that sweetness was significantly higher when listening to a liked “Creamy” soundtrack than a less liked “Rough” soundtrack when consuming chocolate.

LV was perceived to be more dominant in sweetness, creaminess, and vegetable under the US condition. On the other hand, LLV was less dominant in sweetness under the US condition. In this study, LLV also evoked more negative emotions than did the LV during the US condition. Similarly, Jaeger et al. (2014) also showed negative emotions (bored, aggressive and guilty emotions) elicited more dominant sensory attributes (cocoa, dry, bitter and sour) when consuming the less liked plain chocolate (85% cocoa). To date, no studies have reported how sensory attributes of liked and less liked foods are influenced by sounds varying in pleasantness.

5 Conclusions

The present study was designed to compare the temporal perception of emotional (chocolate milkshake, CM) and non-emotional (vegetable ice cream) foods when consumed while listening to pleasant and unpleasant sounds. In addition, the emotional states of participants were obtained in order to understand how th pleasantness of sounds influenced the perceived flavour of the different foods. CM was found to elicit more emotions compared to vegetable ice creams. In addition, LV elicited more emotions than LLV. This study provides the first comprehensive assessment of how sounds varying in pleasantness can influence liked and less liked foods. Another major finding was that sounds varying in terms of pleasantness elicited different emotions that, in turn, influenced sensory ratings when eating emotional and non-emotional foods. CM brought forth more emotions compared to vegetable ice creams and, in addition, LV elicited more emotions compared to LLV. Therefore, consuming foods under sound conditions that varied in terms of their pleasantness can influence changes in both the perceived sensory attributes and emotional responses. Emotional (CM) and liked non-emotional (LV) foods when consumed in the PS condition elicited positive emotions that evoked sweetness and milky attributes. Emotional (CM) and less liked non-emotional (LLV) foods when consumed in the US condition elicited negative emotions evoking thickness, cocoa, and earthy attributes. These findings therefore help to further our understanding of how the flavour of different foods can be modulated using sound conditions that vary in terms of their pleasantness.

The scope of the present study was limited in terms of the sound conditions used, that is, they only varied in valence. It would therefore be interesting in future research to assess the effects of sound conditions that varied in other emotional dimensions on the perception of food. In addition, the effect of sounds on specifically emotional eating can be further explored. One implication of the findings reported here is that both affective auditory stimuli and emotional aspects of food should be considered when investigating temporal changes in the perception of food under different sound conditions.

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Appendices

Appendix 1. Nutritional information of chocolate milkshake.

Frosty Shake (small)		Serving size	1 each	Weight (g)	309.0
Kilojoules	1677.0	Calories	400.5	Protein	9.1
Total fat	14.1	Saturated fat	9.4	Carbohydrates	59.7
Sugar	54.5	Sodium (mg)	102.2		

Reference: https://www.wendys.co.nz/our-food/nutritional

Appendix 2. Liking of different flavours of vegetable ice creams ($p < 0.05$).

Ice cream flavour	**Mean liking**	**Standard deviation of liking**
Eggplant	5.59^{a}	2.55
Spinach	5.33^{a}	2.61
Celery	5.30^{ab}	2.13
Asparagus	3.81^{bc}	2.86
Broccoli	3.53^{c}	2.19
Kale	3.44^{c}	2.39
Leek	1.60^{d}	1.74

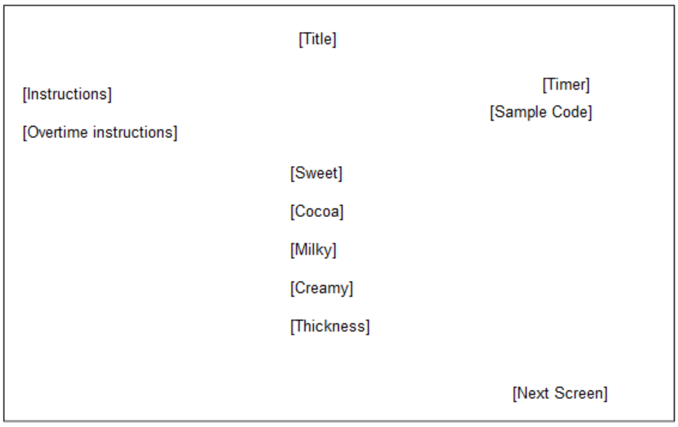
Note: Mean overall liking ratings of vegetable ice cream samples with different small letters (a-d) indicate significant differences in overall liking ratings.

Appendix 3. Sounds used in the present study

Sounds	
Waterfall & jungle sounds	https://soundcloud.com/user-172130693-351905891/waterfall-jungle-sounds-relaxing-tropical-rainforest-nature-sound?si=dbc43061053d48deaccbdfde4c4f099f
Birds chirping	https://soundcloud.com/larson816/birds-chirping?si=dc4ee962164044fd9754b65acd5632e3
River flowing & birds singing	https://soundcloud.com/user-57617419/river-flowing-and-birds?si=ae1eda1e0c1449f3b641fac1bcf05077
Waterfall	https://www.soundsnap.com/water_flowing_waterfall_bright_noise_wide_angle_wav
Thunder & rain	https://soundcloud.com/shvan0077/thunder-and-rain-sounds-of?si=09ee3a300f924ffc90a5aff6c9abf07e
Sea waves hitting rocks	https://soundcloud.com/cornelia-fischer/sea-waves-crushing-against?si=be7b9a11536e4f97abc5353626a7745f
Burning fire	https://soundcloud.com/cole-haywood/crackling-fire-nature-sound?si=39b4dff84b0645c8a9f481223192093d
Outdoor restaurant dining	https://www.soundsnap.com/outdoor_dining_exterior_canadian_restaurant_crowd_victoria_canada_wav
Traffic	https://www.soundsnap.com/ambience_urban_city_roar_rumble_distant_siren_wav
Indoor marketplace	https://www.soundsnap.com/ca5_ambience_indoorfoodmarket_verybusy_wav
Inside an airport	https://www.soundsnap.com/crowds_pearson_airport_in_toronto_large_crowd_some_public_announcements_and_discernible_english_wav
Busy traffic	https://www.soundsnap.com/traffic_busy_with_scooter_cars_wav
Bar	https://www.soundsnap.com/crowds_airport_hotel_bar_in_toronto_small_crowd_with_no_music_some_discernible_english_wav
Background noise in fast food restaurant	https://www.soundsnap.com/restaurant_fast_food_walla_01_wav

Appendix 4. Representation of the screen used for the temporal dominance of sensation method of sensory evaluation of a) chocolate milkshake and b) vegetable ice cream.

(a) Chocolate milkshake



(b) Vegetable ice cream

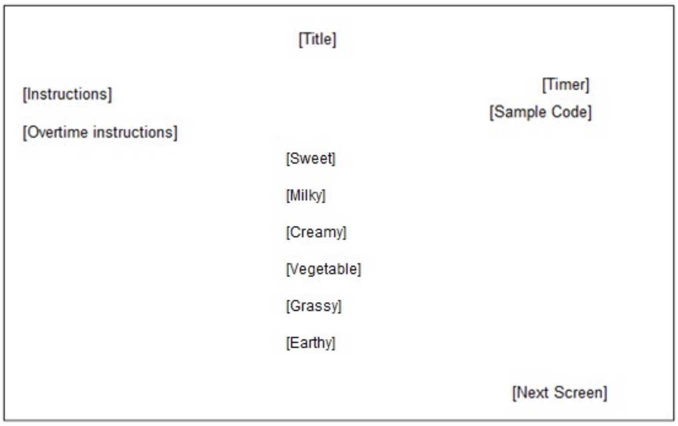


Table 5. Description and examples of emotion terms used in this study.

Emotion Attribute		Examples	Description
Active	Positive	Drinking wine with friends or parents at a party	Engaging or ready to engage in physically energetic pursuits
Annoyed	Negative	The store sold food that was out-of-date	Slightly angry; irritated
Anxious	Negative	I made a big mistake, and the opponent took immediately advantage of my mistake	Feeling or showing worry, nervousness, or unease about something with an uncertain outcome
At ease	Positive	On holiday with the family	Free from worry or awkwardness; relaxed
Boredom	Negative	One can be bored by eating traditional meals; simple biscuits, tasteless and dry	The state of feeling bored
Calm	Positive	An atmosphere where no one is fighting or arguing and there is no stress or tension	Not showing or feeling nervousness, anger, or other strong emotions
Energetic	Positive	A person who very active and does not feel at all tired.	Showing or involving great activity or vitality
Enthusiastic	Positive	Cheerful picture and graphics; drinking at a party	Having or showing intense and eager enjoyment, interest, or approval
Excited	Positive	A barking dog when the mailman comes to the door	Very enthusiastic and eager
Interested	Positive	Feel like eating product; curious about taste	Having an interest or involvement; not impartial
Joy	Positive	Happy with product information; strong smell makes you happy; cheerful picture and graphics	A feeling of great pleasure and happiness
Lonely	Negative	Eating or drinking alone	Sad because one has no friends or company
Pleasant	Positive	Drinking wine with friends or parents	Giving a sense of happy satisfaction or enjoyment
Relaxed	Positive	Walking on the beach; water, after or during sports activities	Free from tension and anxiety
Restless	Negative	You cannot sit down and pace around more	Unable to rest or relax as a result of anxiety or boredom
Satisfied	Positive	I am satisfied after my late lunch; I am very satisfied with the flavour of this food	Peaceful, happiness, calm, feeling when an outcome is above expectations.
Tired	Negative	Working for 12hrs without break	In need of sleep or rest
Unable to concentrate	Negative	Reading at a noisy bus stop	Can’t focus all one’s attention on a particular object or activity
Uneasy	Negative	A person sitting in a chair with only three legs	Causing or feeling anxiety; troubled or uncomfortable
Unhappy	Negative	Food perceived as being too watery and artificial	Not happy

Appendix 6. Psychoacoustic parameter (Supplementary)

Supplementary 6A - Pleasant sounds

No.	Sharpness [acum][1]	Roughness [asper][2]	Fluctuation strength [vacil][3]
1	3.99	0.42	0.63
2	5.27	0.35	1.21
3	5.82	0.60	0.76
4	4.98	0.37	0.28
5	3.80	0.41	0.52
6	4.34	0.49	0.76
7	4.16	3.21	1.85
Mean	4.62	0.84	0.86
SD	0.75	1.05	0.52

Supplementary 6B - Unpleasant sounds

No.	Sharpness [acum][1]	Roughness [asper][2]	Fluctuation strength [vacil][3]
8	3.37	0.33	1.47
9	2.97	0.41	0.5
10	3.98	0.35	0.76
11	2.98	0.33	1.08
12	3.05	0.35	0.39
13	3.54	0.33	0.71
14	4.1	0.3	0.96
Mean	3.43	0.34	0.84
SD	0.47	0.03	0.37

Footnote:

1. [acum]: In Latin, the expression "acum" is used for sharp. The reference sound producing 1 acum is a narrow-band noise one critical-band wide at a centre frequency of 1 kHz having a level of 60 dB (Fastl & Zwicker, 2007, pp. 239-246).

2. [asper]: the roughness produced by a 1-kHz tone sinusoidal modulated with a modulation frequency of 70 Hz and a degree of modulation of 1 is defined to be one asper (Daniel, 2008).

3. [vacil]: defined for a 60-dB, I-kHz tone 100% amplitude modulated at 4Hz, as producing 1 vacil (from vacilare in Latin, or vacillate in English) (Fastl & Zwicker, 2007, pp. 247-256).