



Changes in flavour, emotion, and electrophysiological measurements when consuming chocolate ice cream in different eating environments

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ABSTRACT

The eating context influences eating behaviour as well as the hedonic response to food. This study investigated temporal changes in the perceived flavour of chocolate ice cream when consumed in a laboratory, café, university study area, and a city bus stop, and further examined how emotion and electrophysiological measures were influenced by these environments. In this study, three measures were obtained from 160 participants. First, temporal changes in multisensory flavour perception after consuming chocolate ice cream in different environments were determined using the Temporal Dominance of Sensations (TDS) method. Second, participants' emotional responses were measured after consuming ice cream using a check-all-that-apply (CATA) list of emotions. Finally, standard electrophysiological measures of heart rate (HR), blood volume pulse (BVP), and skin conductance (SC) were also obtained. When ice cream was consumed in the café, it was associated with positive emotions and a sweet taste/flavour. When consumed in the university study area, it was correlated with both positive and negative emotions, and cocoa and milky flavours. Consumption at the city bus stop was correlated with the most negative emotions, and with roasted and bitter tastes/flavours. The laboratory environment was only correlated with the attributes of 'concentrating' and creamy flavour. SC was significantly increased in the university study area as compared to the laboratory, and HR was significantly decreased in the university study area environment as compared to the bus stop. The evidence from this study therefore indicates that the eating context constitutes an important factor to consider when carrying out sensory testing as participants' emotions, perceptions, and electrophysiological responses are influenced differently dependent upon the eating context.

1. Introduction

The sensory testing of food is often carried out in a laboratory setting in order to accurately analyse the sensory attributes of products (e.g., see Pound, Duizer, & McDowell, 2000). However, in real life, people consume foods in a host of different eating environments, that are mostly typically far removed from that of the science laboratory. However, sensory testing in a controlled environment such as a sensory laboratory might not provide a good indication of food perception as consumption takes place under highly controlled conditions (Hersleth, Ueland, Allain, & Næs, 2005; Kim, Lee, & Kim, 2016; see Spence, 2017a, for a review). Most research has shown that consuming food in a central test location (Hersleth, Mevik, Næs, & Guinard, 2003; Petit & Sieffermann, 2007; Pound et al., 2000), in the home (Dailland-Spinnler

& Issanchou, 1995; Kozłowska et al., 2003; Pound et al., 2000; Zhang, 2017), and in immersive environments (Bangcuyo et al., 2015; Hathaway et al., 2017) result in significantly higher hedonic ratings than when a laboratory environment is used. These studies confirm that food consumption in everyday eating environments may well have more ecological validity than offered by laboratory testing (Kim et al., 2016; Pound et al., 2000). In view of all that has been mentioned so far, one may suppose that the flavour of food and drink may change when eating in different environments. That change might be in terms of either the sensory-discriminative and/or the hedonic response.

Studies on how eating environments influence food perception have mainly focused on acceptability (Bangcuyo et al., 2015; Bell, Meiselman, Pierson, & Reeve, 1994; Jiang, Niimi, Ristic, & Bastian, 2017; King, Weber, Meiselman, & Lv, 2004), and eating behaviour (Stroebele & De Castro, 2004). Very little published research has investigated temporal changes in flavour perception in different eating envi-

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ronments. To date, only Kantono et al. (2018) have investigated the effect of music on flavour dynamics under different environmental conditions (laboratory, immersive, and natural eating environment). The authors demonstrated that cocoaness, sweetness, and milkiness were cited more in the natural eating environment than in the laboratory setting, and bitterness and creaminess were least cited. In addition, it was found that music varying in valence evoked emotions, which influenced the temporal sensory attributes of chocolate gelati in the different eating environments. Flavour perception can be influenced by mood state (i.e., hedonic tone of pleasantness; Seo & Hummel, 2010) and heightened emotional state (Woods et al., 2011; Wang & Spence, 2018). Thus, understanding the relationship between consumer emotions and sensory food perception is important as it may potentially provide a better understanding of consumers' product experiences (Spinelli & Monteleone, 2018).

A number of different sensory science approaches have been developed to assess the emotions associated with food. Most studies use questionnaires that comprise a forced yes/no variant of CATA questions (Cardello & Jaeger, 2016). Valence and arousal are important descriptive features of all emotions that characterise the core level of affect (Barrett, 2016). Emotional valence illustrates the extent to which an emotion is positive or negative, while arousal indicates the strength of the associated emotional state (Russell, 2003). More objective physiological measures known to covary with emotional states (i.e., cardiovascular, respiratory, and skin conductance responses) can also be used. Electrophysiological measurements can covary with food-related emotions (Nijs, Franken, & Muris, 2010). Subjective measures of emotions can be supplemented by measuring autonomic nervous system (ANS) activity that controls organ functions via parasympathetic (relaxation) and sympathetic (activation) branches, which can influence and reflect emotional responses (Kreibig, 2010). Wioleta (2013) reported that physiological signals like blood volume pulse (BVP), blood pressure (BP), skin conductance (SC), and heart rate (HR) can be informative when analysing participants' emotions. Kantono et al. (2019) postulated that an affective mechanism mediated the relationship between music valence and the perception of chocolate gelato. Their study successfully demonstrated the use of electrophysiology measures to augment subjective measurements of emotion in order to explain the temporal changes in perceptions of chocolate gelato while listening to music varying in valence. They reported that both of these measures were robust predictors of changes in flavour perception of gelato while listening to music. The authors explained that an affective (or 'emotion') mechanism mediated the relationship between music valence and the perception of gelato, and suggested that the use of electrophysiological measures could be used to augment subjective measurements of emotion.

A consumer's emotional state can be influenced by the environment in which consumption is taking place (Edwards & Gustafsson, 2008), for instance, due to lighting, background music, spatial layout, and/or temperature (Heung & Gu, 2012). According to the Mehrabian and Russell (1974) model (M-R), participants' emotional responses (i.e., arousal, dominance, and pleasure) can be influenced by environmental factors such as colour, odour, texture, sound, and temperature. Recent studies have demonstrated that restaurant atmospherics have a significant effect on the emotions of consumers in terms of positive emotions (Jang & Namkung, 2009; Jang, Liu, & Namkung, 2011; Jeong & Jang, 2011; Prayag, Khoo-Lattimore, & Sitruk, 2014), arousal (Hyun & Kang, 2014; Ryu & Jang, 2007) and pleasure (Kim & Moon, 2009; see Spence, 2017a, for a review). Danner et al. (2016) further demonstrated that positive emotions were rated significantly higher in the restaurant environment after consuming wine compared to consuming in the home and laboratory environments. These researchers attributed the latter results to the social interactions that participants had in the restaurant. Additionally, Schouteten, De Steur, Sas, De Bourdeaudhuij, and

Gellynck (2017) reported that positive emotions were rated significantly higher at home when consuming yogurt as compared to when in the sensory laboratory. Dorado, Chaya, Tarrega, and Hort (2016) further showed that positive emotions were significantly increased, and negative emotions significantly decreased, when drinking beer in central locations with freely-elicited scenarios (i.e., talking with friends) as compared to the control environment. From these studies, it is evident that emotional experiences of consumers vary in different eating environments. It is hypothesised that these changes may, in turn, influence the multisensory perception of the flavour of ice cream.

Researchers have investigated how environmental factors influence electrophysiological processes. For example, noisy environments with public transport have been shown to increase BP (Belojevic, Jakovljevic, Stojanov, Paunovic, & Ilic, 2008; Dratva et al., 2012; Kjellgren & Buhrkall, 2010; Paunović, Belojević, & Jakovljević, 2014), HR (Belojevic et al., 2008), and SC (Alvarsson, Wiens, & Nilsson, 2010). Environments near shopping centres (Dubowitz et al., 2012) and pedestrian-friendly neighbourhoods (Dubowitz et al., 2012; Li, Harmer, Cardinal, & Vongjaturapat, 2009), by contrast, lead to a significant decrease in BP instead. As electrophysiological measures typically correlate with an individual's emotional state, these studies indicate that environmental factors can induce negative and positive emotions alongside changes in physiological response. Speculatively, then, the types of environments in which the consumer finds themselves will likely also influence their perception of food.

It is evident, then, that studies have now convincingly demonstrated that different eating environments can affect consumers' hedonic, emotional, and electrophysiological responses. Hence, the specific objective of the present study is to determine how the temporal aspects of flavour perception, consumer emotion, and electrophysiological measurements are influenced by the laboratory and real eating environments when consuming chocolate ice cream. It was hypothesized that different eating environments would influence affective states that would, in turn, result in temporal changes in the multisensory perception of ice cream. The relationship between sensory, emotion, and ANS measures obtained after consuming ice cream in the different eating environments will then be further evaluated.

2. Materials and methods

2.1. Experimental procedure

The flow chart shown in Fig. 1 depicts the experimental design used in this research. Chocolate ice cream was consumed by participants in four different environments as shown in Fig. 2: (a) sensory testing laboratory, (b) café, (c) bus stop, and (d) university study area. In each environment, electrophysiological, sensory and emotional measures were obtained. First, electrophysiological measurements were obtained while the participants were seated comfortably in each environment for a 5-min baseline measurement when not consuming ice cream, and finally for 1-min while consuming ice cream. Second, the Temporal Dominance of Sensations (TDS) method was used to measure temporal changes in the flavour of chocolate ice cream over a 45 s period. At the end of TDS assessment, participants rated the affective attributes of the stimuli in terms of valence, arousal, and dominance. The participants also selected emotions elicited by each environment from a list of emotions provided. There were compulsory five minute breaks between electrophysiological, sensory, and emotion measurements.

2.2. Ethics statement

Ethical approval for this study was granted by the Auckland University of Technology Ethics Committee (AUTC 17/202). The partici-

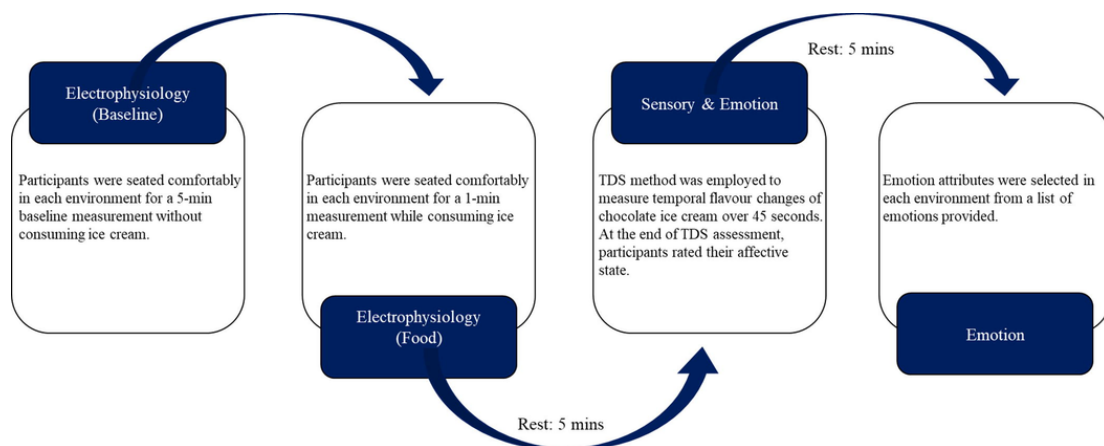


Fig. 1. Experimental design used in the present study.

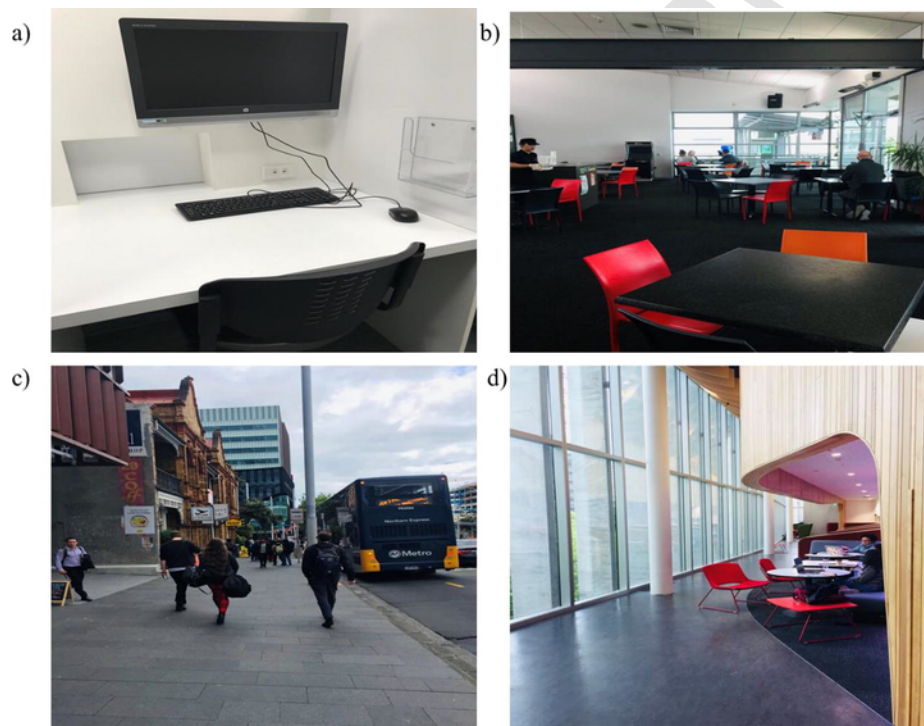


Fig. 2. The laboratory (a), café (b), bus stop (c) and university study area (d) environments where ice cream was consumed.

pants were provided with informed consent forms prior to the commencement of the study.

2.3. Background sound recordings

The background sounds of the different environments (i.e., laboratory, café, university study area, and bus stop) were recorded on a weekday between 11:00 a.m. and 12:00p.m. using a Sennheiser microphone (Series HD 518: Sennheiser Electronics GmbH and Co. KG, Wedemark, Germany) connected to a standard PC sound card. Subsequently, psychoacoustical parameters (tonality, sharpness, roughness, and fluctuation strength) were calculated to characterise the soundscape of each environment (Fastl & Zwicker, 2007). Here, tonality measures the relative content of pure tones, sharpness the relative content of high frequencies, roughness the modulation within low frequencies (15–300 Hz), and fluctuation strength the amplitude modulation of the

recorded soundscapes. National Instruments LabVIEW 2013 software (Austin, TX, USA) was used to calculate the psychoacoustical parameters using its inbuilt sound quality module.

2.4. Sample preparation and presentation

The chocolate ice cream samples were made up of 60% cream, 16% milk, 15.7% sugar, 8% cocoa powder, and 0.3% vanilla extract. An ICE-100 ice cream and gelato maker (Cuisinart, America) was used to make chocolate ice cream. A scoop of chocolate ice cream (5 ± 0.8 g) was placed in individual portion cups (45 mm diameter) and frozen in a commercial-grade freezer (Fisher and Paykel, NZ) at -18°C for at least 24 h prior to serving to ensure sample consistency. All of the samples were thawed for at least two minutes at room temperature before serving. The serving temperature ($-12 \pm 2^\circ\text{C}$) was strictly controlled to maintain consistency.

2.5. Participants

One hundred and sixty participants (50 males, 110 females) aged between 20 and 40 years old were recruited in this study. A between-participants design involved forty participants consuming ice cream samples in different eating environments (laboratory (7 males, 33 females), bus stop (13 males, 27 females), café (19 males, 21 females), and university study area (10 males, 30 females)). Forty participants were chosen to carry out the experiments in each environment in order to achieve a statistical power of 0.90–0.95 using the Cohen's *d* calculation of 0.8 (Kenny, 1987) as used in our previous research (see Kantono, Hamid, Shepherd, Yoo, et al., 2016; Kantono, Hamid, Shepherd, Lin, et al., 2016; Kantono, Hamid, Shepherd, Yoo, Carr, et al., 2016). The participants were recruited by advertisements placed around the university, and were excluded if they smoked, or reported any health problems. The study was carried out any time between 11:00 am and 2:00 pm, to ensure that all participants completed the experiment before lunch.

2.6. Temporal dominance of sensation (TDS) training

Participants first underwent a 15-min training session dedicated to the TDS method. First, the participants were introduced to the concept of dominance defined as the sensory sensation of food that directed the participant's attention at any given time. The participants were instructed that dominance might switch if a new sensation arrived (Labbe, Schlich, Pineau, Gilbert, & Martin, 2009; Pineau et al., 2009). Furthermore, the intensity of the dominant attribute was rated by participants using an unstructured line scale anchored with "none" and "extreme" (Pineau et al., 2009). The participants were also familiarized with the measure of flavour sensations of ice cream using TDS through exposure to a dummy TDS trial during training.

2.7. TDS analysis

TDS was used to capture the temporal flavour changes in ice cream flavour as described by Pineau et al. (2009). Selected sensory attributes (cocoa, milky, creamy, vanilla, roasted, sweet, and bitter) were measured using an unstructured line scale with anchors labelled with "none" and "extreme" at each end (Kantono, Hamid, Shepherd, Yoo, et al., 2016). For each eating environment, a TDS session lasted for 45 s. The TDS screenshot of what participants viewed when they carried out the experiment in this study is shown in Fig. 3. All sensory data acquisition

was undertaken by using the FIZZ Acquisition software (v. 2.46b: Biosystemes, France).

2.8. Emotional responses in different eating environments

The Self-Assessment Manikin (SAM) as described by Bradley and Lang (1994) was used in this study to analyse participants' affective responses after consuming ice cream in the different eating environments. Table 1 summarizes the definitions of valence, arousal, and dominance. The SAM emotion attributes were measured using a 15 cm unstructured line scale with anchors labelled using the labels shown in Table 1.

The participants also had to select emotional attributes after consuming the ice cream. A list of twenty emotions were obtained from a focus group of 40 participants who selected the emotions that they experienced in different environments (laboratory, café, bus stop, and university study area) from the Profile of Mood States Questionnaire (McNair, Lorr, & Droppleman, 1971), Multiple Affect Adjective Check-list-Revised (Lubin & Zuckerman, 1999), Positive and Negative Affect Schedule (Watson, Clark, & Tellegen, 1988) and Geneva Affect Label Coder (Scherer, 2005). The participants selected emotions from the check-all-that-apply (CATA) emotion questionnaire provided while eating ice cream in the different environments. The emotions provided are shown in Table 2.

2.9. Electrophysiological measures

Standard electrophysiological measures including heart rate (HR), blood volume pulse (BVP), and skin conductance (SC) were measured using a Nexus 10 device (24-bit A-D converters) and BioTrace + software (version V2011B1. 2004–2010 Mind Media B.V. Roermond, NL). The BioTrace + software was used to analyse the obtained electrophysiological data. Electrodes (gelled Ag/AgCl) were used to measure the participant's cardiac and sweat gland activity. SC response was measured by attaching sensors to the third and fourth digits (middle phalanx) of the non-dominant hand. HR and BVP signals were recorded with the Nexus-10-Heart Rate sensor attached to the left index finger using the photoplethysmography technique.

Electrophysiological measurements were collected for a 5-min baseline without eating ice cream, and a further one-minute while eating chocolate ice cream (5 ± 0.8 g). With the five minutes baseline measurement, participants were seated in a relaxed and upright position, and were asked not to move their non-dominant hand during the experiment. All of the signals were recorded at a data sampling rate of 32 data samples per second using the BioTrace + software.

Sensory Testing of Chocolate Ice Cream

Please consume the sample following the instructions below, and rate it on the unstructured line scale for the most dominant sensation each second.

Sweet

Bitter

Milky

Creamy

Cocoa

Vanilla

Roasted

Fig. 3. The TDS assessment screen as used by participants.

Table 1
Description of the Self-Assessment Manikin affect attributes provided to participants.

Affect attributes	Description	Anchors	Reference
Valence	The pleasantness of the stimulus	From 'unpleasant' to 'pleasant'	Soleymani, Chanel, Kierkels, & Pun, 2008; Warriner, Kuperman, & Brysbaert, 2013
Arousal	The intensity of emotion provoked by the stimulus	From 'calm' to 'exciting'	Soleymani et al., 2008; Warriner et al., 2013
Dominance	The degree of attentional control exerted by the stimulus	From 'not controlling attention' to 'controlling attention'	Warriner et al., 2013

Table 2
The list of emotions used in this study.

Emotion attribute	Valence	Source	Reference
Unable to concentrate	Negative	Profile of Mood States Questionnaire	McNair et al., 1971
Lost	Negative	Multiple Affect Adjective Checklist-Revised	Lubin & Zuckerman, 1999
Uncertain about things	Negative	Profile of Mood States Questionnaire	McNair et al., 1971
Disgusted	Negative	The Positive and Negative Affect Schedule	Watson et al., 1988
Tired	Negative	The Positive and Negative Affect Schedule	Watson et al., 1988
Tense	Negative	Profile of Mood States Questionnaire	McNair et al., 1971
		The Positive and Negative Affect Schedule	Watson et al., 1988
Composed	Negative	Multiple Affect Adjective Checklist-Revised	Lubin & Zuckerman, 1999
Unhappy	Negative	Profile of Mood States Questionnaire	McNair et al., 1971
Annoyed	Negative	The Positive and Negative Affect Schedule	McNair et al., 1971
		Multiple Affect Adjective Checklist-Revised	Watson et al., 1988
Anxious	Negative	Profile of Mood States Questionnaire	McNair et al., 1971
Cheerful	Positive	The Positive and Negative Affect Schedule	Watson et al., 1988
Calm	Positive	The Positive and Negative Affect Schedule	Watson et al., 1988
At ease	Positive	The Positive and Negative Affect Schedule	Watson et al., 1988
Concentrating	Positive	The Positive and Negative Affect Schedule	Watson et al., 1988
Joy	Positive	The Geneva Affect Label Coder	Scherer, 2005
Pleasure	Positive	The Geneva Affect Label Coder	Scherer, 2005
Satisfied	Positive	Profile of Mood States Questionnaire	McNair et al., 1971
Excited	Positive	The Positive and Negative Affect Schedule	McNair et al., 1971
Positive	Positive	The Geneva Affect Label Coder	Scherer, 2005
Happy	Positive	The Positive and Negative Affect Schedule	Watson et al., 1988
		Multiple Affect Adjective Checklist-Revised	Lubin & Zuckerman, 1999

2.10. Data analysis

2.10.1. TDS curve

In this study, TDS dominance curves were used to exhibit the dominance ratings of all attributes over time by using in-built spline-based smoothing algorithm in the FIZZ software (Pineau et al., 2009). Temporal dominance curves display the percentage of participants who recognised the prescribed attributes as being dominant at a given time (Pineau et al., 2009). TDS time was presented as standardized time (ST), and data was converted to percentages (0–100%) (Ares et al., 2015). The significant (P_e) and the chance (P_0) levels were determined from the panel curves, and calculated according to Pineau et al. (2009).

2.10.2. Canonical variate analysis

Canonical Variate Analysis (CVA) was performed on emotion and flavour perception data. CVA minimizes residual variability and maximizes the distances between samples (Delarue & Sieffermann, 2004), and carried out using XLSTAT (version 2018.5) (Addinsoft, USA). Additionally, Multivariate Analysis of Variance (MANOVA) tests were used to determine if significant differences existed between the four eating environments in terms of standardized durations of flavour ($\alpha = 0.05$).

2.10.3. TDS trajectory plots

Principal component analysis (PCA) was carried out on the dominance rates of every dominant attribute, over time, after consuming chocolate ice cream by using XLSTAT (Version 2018.5) (Addinsoft, USA). The PCAs were used to provide a global representation of the trajectory of environmental condition in relation to the evolution of each dominance in flavour perception based on the first and second principal components. The dominant flavour trajectories in each environment are illustrated by connecting the time points graphically (from the initial score (t_0) to the last (t_{100}) point). The time points were 0%, 10%, 20%...100% of the TDS standardized time (Saint-Eve, Panouille, Capitaine, Deleris, & Souchon, 2015), with a total of 11 standardized time points for each environment.

2.10.4. Analysis of emotion responses

Cochran's Q test was used to analyze the frequencies of emotional responses in the different environments using XLSTAT (Version 2018.5) (Addinsoft, USA). The emotional data was dichotomised (0: not selected, 1: selected). Multiple pairwise comparisons using the Marascuilo procedure were applied for analyses that reached statistical significance ($\alpha = 0.05$) (Addinsoft, USA).

2.10.5. Electrophysiological measurement

Prior to analysis, Grubb's test was performed to remove outliers from the electrophysiology data. Average values of electrophysiological indices (i.e., BVP, SC and HR) were calculated with reference to a five-minute baseline measurement. The percentage change from baseline was calculated according to Zhang and Han (2009):

$$\text{Percentage change (\%)} = \frac{(\text{raw value} - \text{mean baseline value})}{\text{mean baseline value}} \times 100$$

A one-way ANOVA was carried out in order to investigate significant differences for the percentage change in electrophysiological measures while consuming ice cream in the different environments. In addition, a two-way ANOVA was carried out on the percentage change in electrophysiological measurements in the different environments and gender effects as factors. This enabled us to explore gender effects for the electrophysiological measures obtained when participants consumed ice cream in the different environments as genetically-deter-

mined individual differences may exist in flavour perception between men and women (though see Spence, 2019, for a recent review). The Tukey *post-hoc* comparisons tests were used when significance was found (Addinsoft, USA).

2.10.6. Multiple factor analysis

Multiple Factor Analysis (MFA) enables the simultaneous analysis of several sets of variables in order to study the relationship between the samples (observations) and dependent variables. In this study, MFA was applied to the TDS sensory duration measures, as well as emotional CATA responses and ANS measures obtained from this study. This allowed the relationship between the sensory responses to emotion and ANS measurements to be further explored.

3. Results

3.1. Psychoacoustic characteristics of the soundscapes

The psychoacoustical characteristics of sounds in the different eating environments are presented in Table 3. The café soundscape had the highest sharpness, tonality, and fluctuation strength values as compared to the bus stop, university study area and laboratory environments. In addition, the bus stop soundscape had the highest roughness followed by café, laboratory and the university study area environments.

Table 3

Psychoacoustic parameters of sounds in the lab, café, university study area, and bus stop environments.

Psychoacoustic parameters	Bus stop	Café	Lab	University study area
Sharpness (<i>acum</i>)	2.27	2.35	1.1	1.59
Roughness (<i>asper</i>)	0.14	0.0018	0.00031	0
Fluctuation Strength (<i>vacil</i>)	0.65	2.50	0.14	1.66
Tonality (<i>son</i>)	0	0.014	0	0

3.2. Temporal dominance of sensations

Fig. 4 depicts the spline smoothed TDS curves describing the dominance rate of various ice cream attributes as consumed in the different environments. The calculated chance and significance levels were between 15% and 20%, respectively. Attributes below 20% (*re*: significance level) will not be discussed further here. It can be seen that although sweetness was the first dominant attribute in all four environments, its dominance varied over time.

For the laboratory environment, a longer and higher duration of sweetness was evident, with a maximum dominance rate of 46% at the start mastication that became less dominant until 26% ST. Creaminess was dominant from 26 to 37% ST, with a maximum rate of 28% at 30% ST. Sweetness then again became dominant from 50 to 67% ST. Roasted was dominant from 81 to 87% ST, reaching a maximum dominance of 25% at 84% ST. Finally, cocoa was dominant from 92% ST until the end of the measurement.

In the university study area, sweetness was dominant at the start and slowly decreased from a maximum dominance rate of 33% between 0 and 9% ST. Milky was dominant from 9 to 15% ST, reaching a maximum dominance of 31% at 13% ST. Cocoa had a higher dominance rate and longer duration from 19 to 73% ST as compared to the control laboratory environment, reaching a maximum rate of 38% at 25% ST.

Sweetness was dominant from 0 to 28% ST, reaching a maximum rate of 48%, and creaminess was dominant from 28% ST to 38% ST, with a maximum rate of 28% at 34% ST in the café similar to the laboratory environment. However, cocoa was observed to be the dominant attribute at several evaluation points after 38% ST in the café, which was different from other environments. It was dominant from 38% ST to 52% ST, 60 to 80% ST, and 87 to 93% ST reaching a maximum rate of 32% at 49% ST, at 76% ST, and 30% at 90% ST, respectively.

At the bus stop, sweetness was dominant at the start and slowly decreased from a maximum dominance rate of 38% between 0 and 10% ST similar to the laboratory. However, bitterness was the dominant attribute thereafter at several points of evaluation different to the other three environments. It was dominant between 10–30% ST and 36–79% ST, reaching a maximum rate of 38% at 35% ST, and 30% at 42, 58

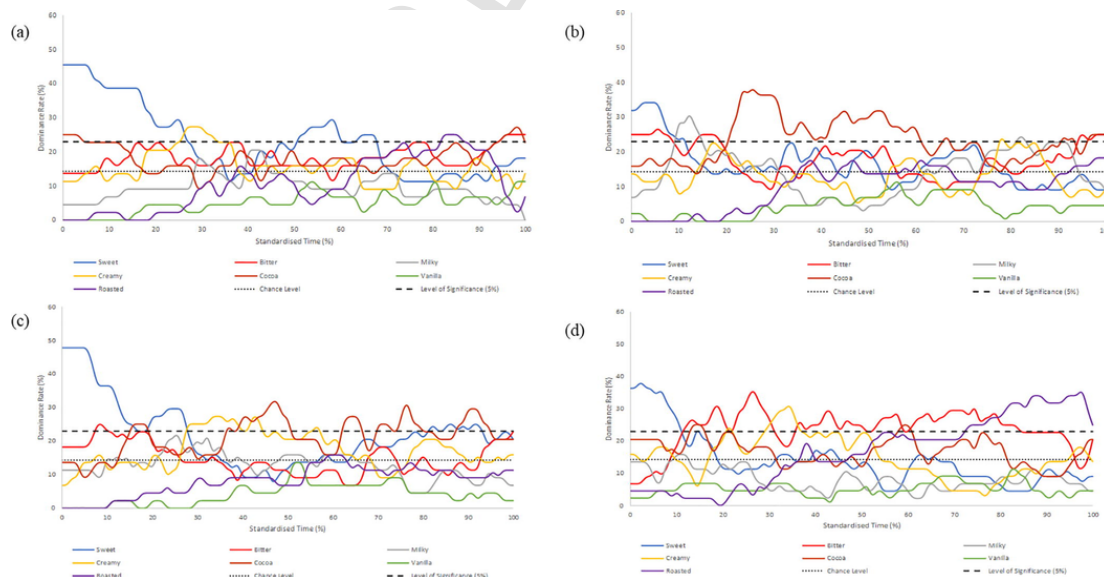


Fig. 4. Panel dominance rates (%) of the seven sensory attributes presented in the TDS sessions expressed in standardized time (%). TDS curves are for the four environments: sensory laboratory (control) (a), university study area (b), café (c), and bus stop (d).

and 74% ST. Roasted was dominant from 79% ST to the end of the evaluation, with a maximum dominance rate of 35% at 98% ST.

3.3. Flavour trajectories of chocolate ice cream in different environments

A series of PCAs were undertaken to further understand and compare the dominance rate of sensory perception during the standardized time from the beginning of flavour perception and the time of swallowing ice cream in the different environments. The first two PCA components represented 52.57% of the total variance observed between samples (see Fig. 5). For each of four environments, a trajectory of perceived dominant attributes was shown. Sweetness was always the first perceived attribute in the laboratory, university study area, bus stop, and café environments at 20%, 7%, 12%, and 20% of the trajectory ST, respectively. This finding agrees with the TDS sensory profile results shown in Fig. 4. In the café environment, milkiness and cocoa were at 32% and 58% of the trajectory time, respectively. Creamy and sweet flavours were then perceived at the end of mastication, at 94% and 96% of the trajectory time, respectively, in the café. In the study space, roasted, vanilla and cocoa were perceived after sweetness, at 45%, 50%, and 69% of the trajectory times, respectively. In the laboratory, creamy and cocoa flavours were perceived at 45% and 48% of the trajectory times respectively. Cocoa, vanilla and roasted were further perceived at 72%, 74%, and 86% of the trajectory times, respectively. In the bus stop environment, bitter was mainly perceived at 22%, 38% and 45% of the trajectory times.

3.4. Relationship between perception of ice cream and different eating environments

Canonical variate analysis was used to further summarize the standardized duration of flavour perception when ice cream was consumed

in different environments. Fig. 6 describes the first two canonical variates which explained 95.20% of the data. The 90% ellipse represents the multidimensional confidence intervals of means (Peltier, Visalli, & Schlich, 2015) of the standardized duration of flavour. The separation of the ellipses suggests that the flavour depended upon the environment in which the ice cream was consumed.

The Hotelling-Lawley MANOVA analysis results showed significant differences between the standardized duration of flavour perception of chocolate ice cream in the four eating environments ($F_{(7, 168)} = 2.682$, $p < 0.05$). The laboratory was only associated with the creamy attribute, and the café was related to sweet taste. The study space was associated with milky and cocoa flavours, while the bus stop environment was related to roasted and bitter flavours.

3.5. Affective dimensions

Participants rated the affective dimensions of the four different environments after consuming ice cream. Fig. 7 shows that the four eating environments were judged to be significantly different in terms of their valence, arousal, and dominance.

The bus stop environment was rated significantly lower in terms of valence, arousal, and dominance compared to the laboratory, café, and university study area. The university study area and café were significantly higher in terms of valence and arousal, respectively, when compared to the bus stop environment.

3.6. Emotion responses in the different eating environments

All the selected emotions listed in Table 4 were based on a pilot trial carried out using 97 participants in four different environments (sensory laboratory, bus stop, café, and study space) in the vicinity of Auckland University of Technology. The pilot trial revealed that the

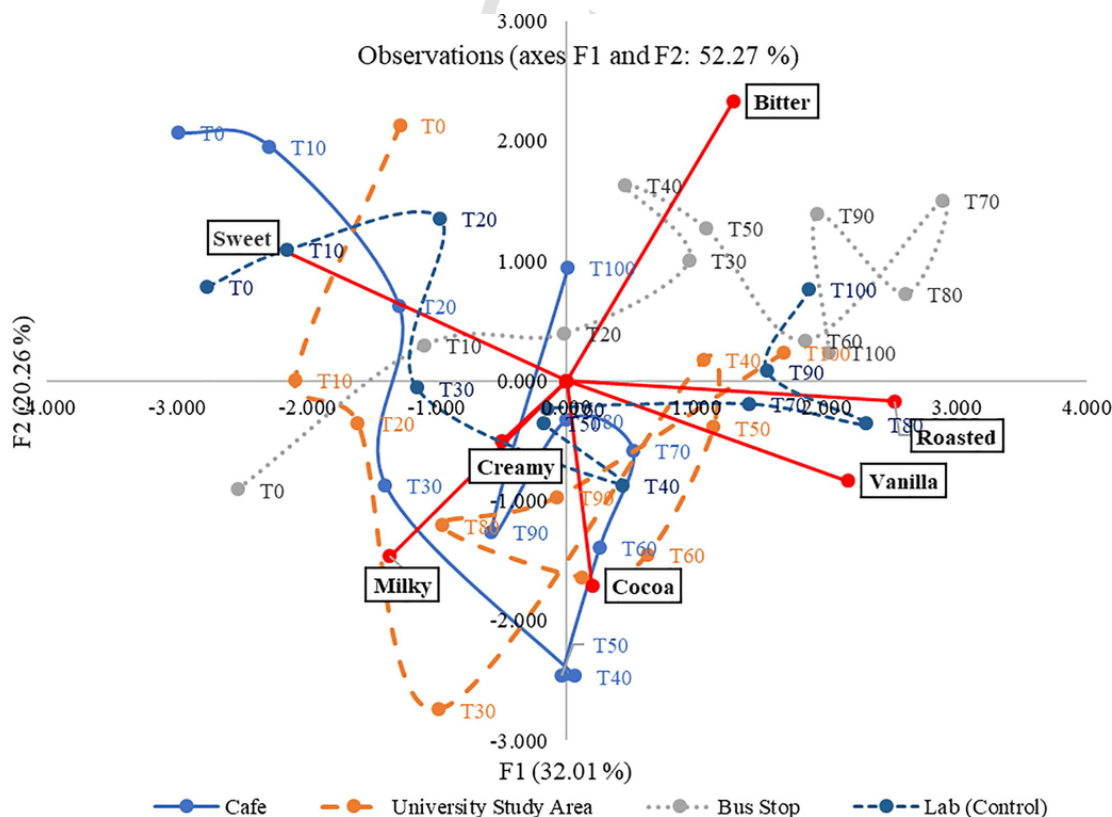


Fig. 5. Principal component analysis (PCA) biplot showing the flavour trajectories of chocolate ice cream consumed in the laboratory, café, study area, and bus stop environments. Each point represents 10% TDS standardized trajectory period (e.g., T0: 0% ST; T100: 100% ST).

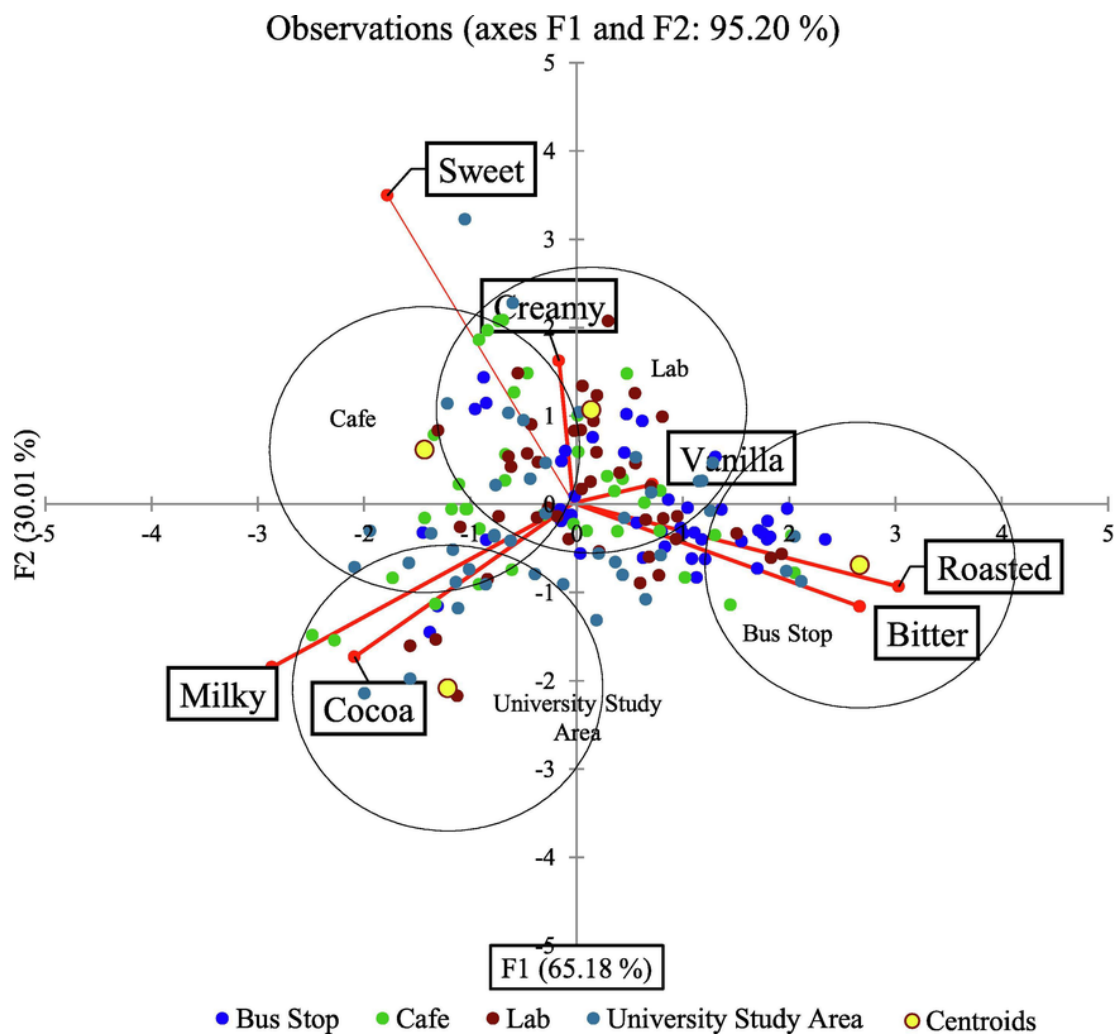


Fig. 6. Canonical Variate Analysis biplot of dominance durations of sensations. Hotelling-Lawley MANOVA test showed significant product differences based on sensory attributes.

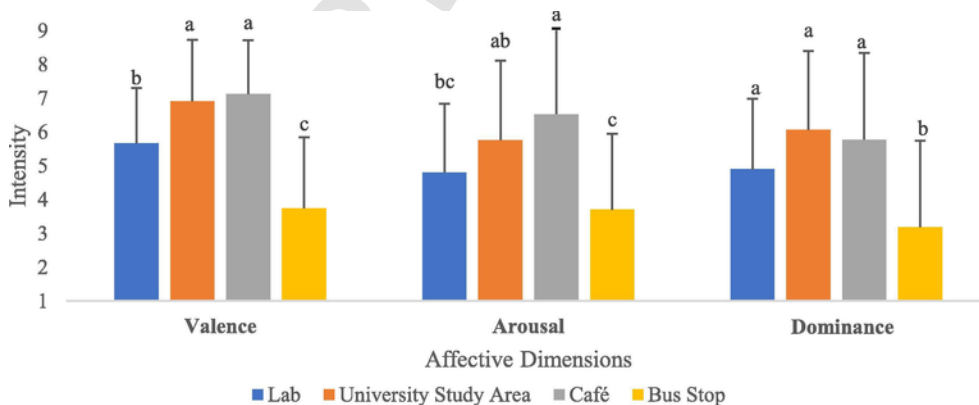


Fig. 7. Affective ratings of valence, arousal, and dominance in different environments (laboratory, university study area, café and bus stop) after consuming chocolate ice cream. The superscript letters ^{a,b,c} indicate: mean affective ratings of environments with different letters indicating significant differences in affective ratings. Error bars indicate the standard deviation.

university study area was associated with the highest number of positive emotions followed by the café, laboratory and bus stop. The bus stop, on the other hand, had the highest number of negative emotions attributed to it.

The frequencies of the emotion responses expressed by the participants revealed significant differences between the four environments (see Table 4) where different superscripts denote significant differences of each emotion in different environment. Frequency of the concentrat-

ing attribute was significantly higher in the laboratory environment as compared to the university study area and bus stop environments. Frequencies of positive emotions of happy, positive, pleasure, joy, at ease and cheerful were significantly higher in the café and university study area environments as compared to the bus stop environment. On the other hand, frequencies of negative emotions of unable to concentrate, uncertain about things, negative, tired, tense, unhappy, annoyed, and anxious were significantly higher for the bus stop environment as com-

Table 4

Self-rated emotions following the consumption of chocolate ice cream under different environments (laboratory, university study area, café, and bus stop). * represents significance using the Cochran's Q test for the emotion terms across the four environments. The superscripts ^{a,b,c} denote frequencies of emotions that are significantly different ($p < 0.05$) across the environment conditions for each emotion.

Emotion	Lab	University study area	Café	Bus stop	p value
Unable to concentrate	2 ^a	0 ^a	4 ^a	16 ^b	<0.0001*
Lost	1 ^a	13 ^b	0 ^a	2 ^a	<0.0001*
Uncertain about things	5 ^a	3 ^a	5 ^a	13 ^b	0.0003*
Negative	0 ^a	0 ^a	0 ^a	12 ^b	<0.0001*
Tired	11 ^a	18 ^{ab}	15 ^a	25 ^b	0.0004*
Tense	12 ^a	11 ^a	2 ^a	26 ^b	<0.0001*
Composed	3 ^a	15 ^b	2 ^a	0 ^a	<0.0001*
Unhappy	10 ^a	2 ^a	4 ^a	29 ^b	<0.0001*
Annoyed	2 ^a	0 ^a	0 ^a	16 ^b	<0.0001*
Anxious	5 ^{ab}	6 ^{ab}	1 ^a	11 ^b	0.001*
Cheerful	16 ^{ab}	19 ^b	24 ^b	8 ^a	0.001*
Calm	16 ^a	27 ^b	15 ^{ab}	12 ^a	0.007*
At ease	14 ^a	40 ^b	32 ^b	8 ^a	<0.0001*
Concentrating	14 ^a	5 ^b	7 ^{ab}	5 ^b	0.018*
Joy	18 ^b	30 ^b	25 ^b	3 ^a	<0.0001*
Pleasure	18 ^a	31 ^b	31 ^b	9 ^a	<0.0001*
Satisfied	16 ^a	16 ^a	29 ^b	7 ^a	<0.0001*
Excited	11 ^{ab}	18 ^b	10 ^{ab}	4 ^a	0.002*
Positive	12 ^{ab}	17 ^{bc}	25 ^c	3 ^a	<0.0001*
Happy	17 ^b	37 ^c	35 ^c	3 ^a	<0.0001*

pared to the laboratory and café environments after consuming chocolate ice cream.

3.7. Relationship between emotions and different eating environments

The results of CVA are shown in Fig. 8, with the first two canonical variates explaining 94.05% of the data. The Hotelling-Lawley MANOVA analysis results ($F_{(63,343)} = 10.682$, $p < 0.001$) revealed significant differences between emotional responses when ice cream was consumed in the different environments. The bus stop was correlated to negative emotions of tense, tired, negative, anxious, annoyed, unhappy, unable to concentrate, and uncertain about things. The study space was correlated to the negative emotions of lost and composed,

and positive emotions of calm, excited, and at ease. The café was correlated to positive emotions of joy, happy, pleasure, cheerful, positive and satisfied. The laboratory was only associated with the attribute 'concentrating'.

3.8. Relationship between sensory and emotional responses perceived after consuming ice cream in the different eating environments

The CVA plot in Fig. 9 depicts the relationship between the standardized duration of perceptions and the frequencies of emotional responses, obtained as ice cream was consumed in different environments. The first two canonical variates explained 93.83% of the data. The 90% confidence ellipses (Peltier et al., 2015) demonstrated that the frequencies of emotions and flavour perception of ice cream differed significantly in the four different eating environments. A Hotelling-Lawley MANOVA results showed significant differences ($F_{(84,336)} = 8.433$, $p < 0.001$) between perceptual and emotional responses by those consuming ice cream in the different environments. The positive emotions of happy, pleasure, joy, cheerful, positive and satisfied were associated with sweet flavour in the café environment. In contrast, the negative emotions of tense, tired, anxious, negative, annoyed, unable to concentrate, unhappy, and uncertain about things were associated with bitter and roasted flavours at the bus stop. In addition, concentrating was related to creamy flavour in the laboratory environment. Finally, the positive emotions of calm, at ease, and excited, and negative emotions of lost and composed, were associated with cocoa and milky in the university study area environment.

3.9. The effect of eating ice cream in different environments upon electrophysiological responses

Consuming ice cream in the different eating environments significantly influenced SC ($F_{(3,156)} = 3.149$, $p < 0.05$) and HR ($F_{(3,156)} = 2.673$, $p < 0.05$). Fig. 10 reveals that SC increased significantly when eating ice cream in the study space as compared to the laboratory. HR was significantly lower in the study space compared to the bus stop after consuming ice cream. No significant difference was found in BVP amplitude ($F_{(3,156)} = 0.202$, $p > 0.05$) when eating ice cream in each of the different environments.

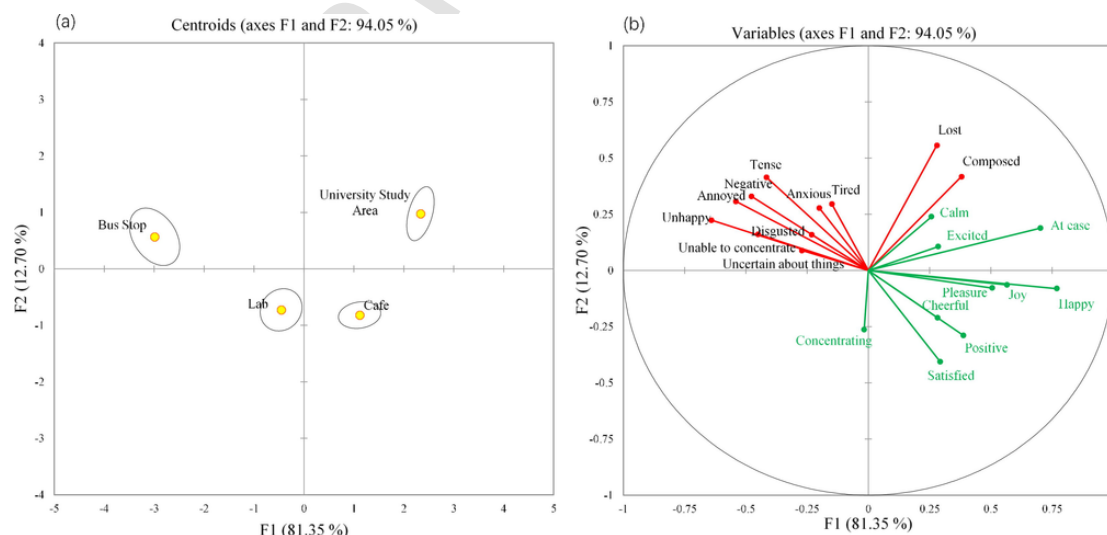


Fig. 8. Canonical Variate Analysis scores and loadings plots of emotional response in different eating environments. Hotelling-Lawley MANOVA test showed significant product differences ($F_{(63,343)} = 10.682$, $p < 0.001$) based on emotion attributes, (a) centroid variables of each environment which are correlated with the two factors on the factor axes, (b) variables of each emotion attribute which are correlated with the two factors on the factor axes. To aid visualisation, positive emotions are labelled in green while negative emotions are labelled in black (for interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

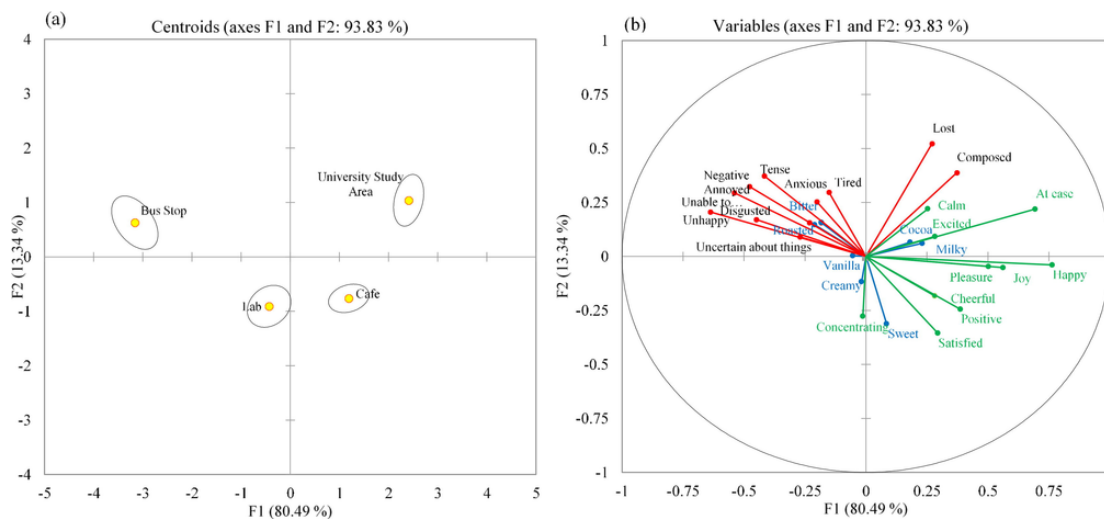


Fig. 9. Joint Canonical Variate Analysis scores and loadings plots of dominance durations of sensations and emotion responses. Hotelling-Lawley MANOVA test showed significant product differences ($F_{(84,336)} = 8.433$, $p < 0.001$) based on sensory attributes and emotion responses. The plots show: (a) centroid variables of each environment which are correlated with the two factors on the factor axes, (b) variables of flavour and emotion attributes which are correlated with the two factors on the factor axes. To aid visualisation, positive emotions are labelled in green while negative emotions are labelled in black, and sensory attributes are labelled in blue (for interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

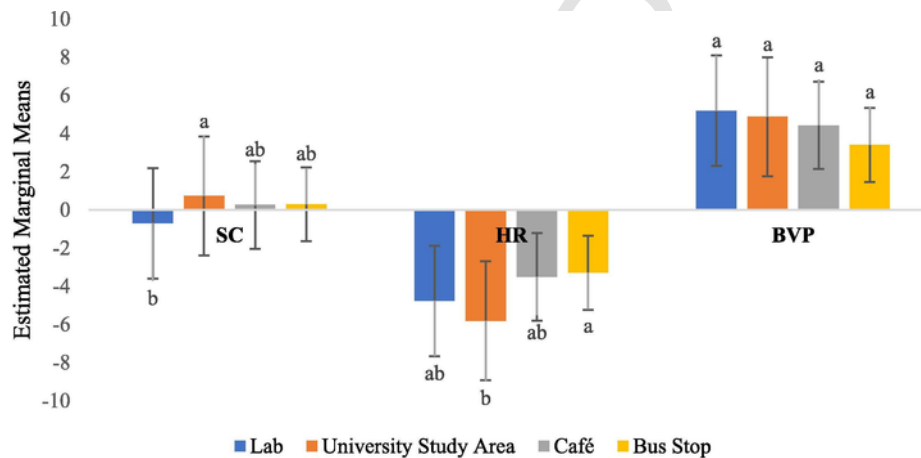


Fig. 10. Skin conductance (SC), blood volume pulse (BVP) amplitude, and heart rate (HR) values calculated based on changes between baseline (without eating ice cream) and one-minute of ice cream consumption in laboratory, café, university study area and bus stop environments. Different ^{a,b,c,d} superscripts indicate significant differences in physiological values using the Tukey's multiple comparison tests. The error bars reflect the standard deviations of electrophysiological measurements for each environment.

3.10. Relationship between sensory, emotion, and ANS measures perceived after consuming ice cream in the different eating environments

MFA was used in this study to further understand the relationship between sensory, emotion, and ANS measures in this study. The MFA model further illustrates the relationship of these measures when ice cream was consumed in different eating environments. Eating ice cream in the bus stop environment elicited bitterness and roasted perceptions that were associated with negative emotions, and the electrophysiology measure of SC. On the other hand, eating ice cream the cafe environment elicited sweetness, cocoa, and milky perception that was associated with positive emotions and BVP measure. Additionally, eating ice cream in the university study area elicited cocoa and milky perceptions that were associated with positive emotions, and HR measure.

3.11. The influence of gender on electrophysiological responses in different eating environment

Two-way ANOVA showed a significant main effect for gender and environment on HR ($F_{(7,152)} = 3.153$, $p < 0.01$), but not for SC and BVP measures. Fig. 11 showed that the HR of female assessors significantly decreased in the university study area as compared to the bus stop after eating ice cream. However, the HR of male assessors had no significant differences in the laboratory, café, university study area, and bus stop environments (See Fig. 12).

4. Discussion

4.1. Dominance of ice cream flavour perception varied in the different eating environments

Results from this study have demonstrated that ice cream flavour perception was affected by the consumption environment. In the laboratory, chocolate ice cream was initially dominated by sweetness and

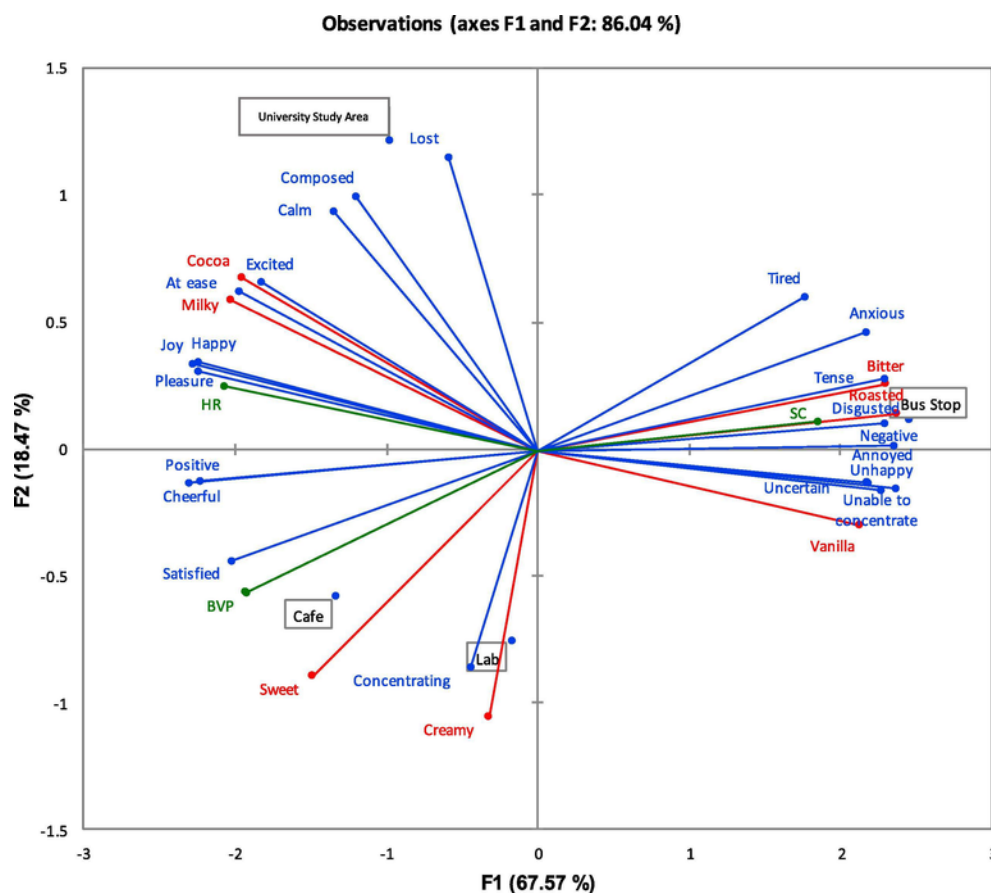


Fig. 11. Multiple Factor Analysis biplot of dominance durations of sensations (red vectors), subjective emotion CATA response (blue vectors), and ANS measures (green vectors) obtained when ice cream was consumed in different eating environments (for interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

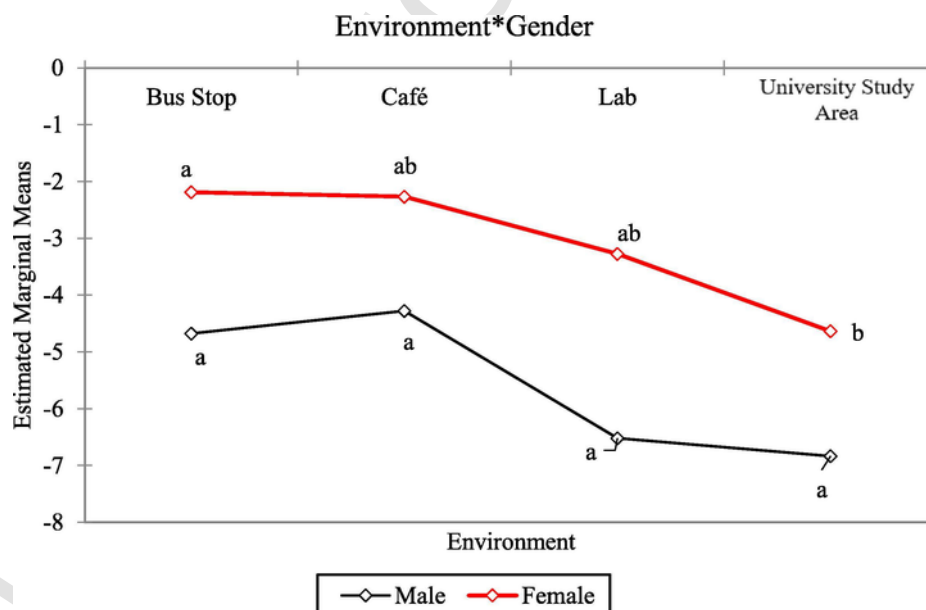


Fig. 12. Physiological measure of heart rate (HR). Values were calculated based on the changes in baseline (without eating ice cream) compared to one-minute of eating ice cream in terms of gender and environment conditions. Different ^{a,b,c,d} superscripts indicate significant differences in physiological values using the Tukey's multiple comparison tests.

creaminess at the start of consumption and then roasted and cocoa at the end. Kantono et al. (2018) recently reported that bittersweet chocolate gelato was initially perceived as sweet and creamy when eaten in a quiet laboratory environment.

Cocoa flavour was dominant in both the café and study space compared to laboratory and bus stop environments, but was at a higher dominance rate in the bus stop from early on until the end of consumption. The consumption of ice cream in the study space was associated

with milky and cocoa flavour, a finding that is consistent with Pound et al. (2000). Petit and Sieffermann (2007) further reported that milkiness ratings of milk-based iced coffee were higher in a meeting room as compared to the laboratory. Zhang (2017) reported that ratings of sweetness and milkiness, of modified protein beverages were significantly higher at home compared to the central location chosen (location not specified).

At the bus stop, sweetness was dominant at the start of mastication but at a lower dominance level than the laboratory and café. This was followed by a prolonged dominance of bitterness that was then interrupted by creaminess. Similarly, the consumption of bittersweet chocolate gelato was associated with bitterness (Kantono, Hamid, Shepherd, Yoo, et al., 2016; Kantono et al., 2018), and significantly less pleasant when listening to disliked music (Kantono, Hamid, Shepherd, Yoo, Carr, et al., 2016). Interestingly, Kantono et al. (2018) also found that creaminess was dominant when first consuming bittersweet chocolate gelato while listening to disliked music. They postulated that this may have been attributable to the fact that disliked music acted as a mild stressor that may lead to creamy flavour being perceived. Torres and Nowson (2007) found that participants desired high-fat food, such as ice cream (Guinard et al., 1997), when stressed (see also Spence, 2017b), which might also explain why creamy was dominant in this study in the noisy and eventful bus stop environment. Interestingly, creaminess of ice cream in Lin, Hamid, Shepherd, Kantono, and Spence (2019) was shown to correlate with the valent park condition. This suggests that perhaps other mechanism instead of the aforementioned stress mechanism may have taken place while listening to soundscapes compared to music.

4.2. Affective dimensions varied in different eating environments

The affective states (i.e., valence, arousal, dominance) of this study based on the Mehrabian-Russell model (M-R model) were used to explain the participants' emotional responses to the four eating environments after consuming chocolate ice cream. In this study, valence ratings were significantly higher in the café and university study area environments after consuming chocolate ice cream as compared to the laboratory and bus stop. Interestingly, this study also revealed that the psychoacoustical characteristics of the cafe soundscape was considered the most pleasant in terms of having the highest fluctuation and low roughness, and the bus stop environment was the least pleasant in terms of having the least fluctuation and highest roughness. Özcan and van Egmond (2012) reported that participants listening to mechanical sounds with higher roughness found them significantly unpleasant compared to cyclic sounds with lower roughness. Ruotolo et al. (2013) further reported that participants were significantly annoyed when watching the audio-visual PIII motorway with higher loudness and roughness compared to the PII motorway condition with lower loudness and roughness. Similarly, Kantono, Hamid, Shepherd, Yoo, Carr, et al. (2016) demonstrated that valence ratings were significantly higher in a café after consuming the dark, bittersweet and milk chocolate gelato compared to a control silent environment.

In this study, the arousal ratings were significantly higher in the café and study space after consuming ice cream than the bus stop and laboratory. High arousal and valence ratings are related to appetitive (i.e., approach) behaviours, while high arousal and low valence ratings were related to defensive (i.e., avoidance) behaviours (Bradley & Lang, 2000; Bradley, Codispoti, Cuthbert, & Lang, 2001). Café and university study area environments evoked desirable sensory attributes (e.g. sweetness, creaminess) in chocolate ice cream. The bus stop (i.e. low arousal, low valence, low dominance) on the other hand evoked non-desirable attributes.

The dominance rating was significantly increased in the study space and café environments after consuming ice cream compared to the bus

stop. Kantono, Hamid, Shepherd, Lin, et al. (2016) also showed that dominance ratings are significantly increased in a café after consuming gelato compared to a control silent condition.

4.3. Ice cream consumed in different environments evoked different emotions

The cognitive theory of emotion argues that the subjective evaluation of emotion by participants can be affected by environment factors (Lazarus, 1991). In addition, Piqueras-Fiszman and Jaeger (2014a,b) have demonstrated that the suitability and context of an eating environment has a significant effect on a multitude of emotions. In this study, the emotional responses of participants varied across the four different environments after eating ice cream. In preliminary trials carried out to identify the emotions elicited by the different eating environments, the university study area had the highest number of positive emotions followed by the café. Many studies have shown that restaurant environments are typically related to positive emotions (Hyun & Kang, 2014; Jang & Ryu, 2007; Prayag et al., 2014). In the present study, positive emotions of pleasure, happy, positive and satisfied were rated significantly higher in the café and university study area compared to the laboratory and bus stop after consuming chocolate ice cream. Prayag et al. (2014) showed that the atmospherics of restaurants in the French Riviera had a significantly positive effect on the positive emotions of consumers in terms of their relaxation, pleasure, and excitement. Jang and Ryu (2007) further reported that the high-quality ambience of high-class restaurants had significant effects on the emotions of happiness, pleased, entertained, and delighted of participants. Similarly, Danner et al. (2016) reported that positive emotions of energetic, happy and loving were rated significantly higher in a restaurant after consuming wine compared to home and the laboratory environments. Dorado et al. (2016) further demonstrated that the positive emotion of excitement was significantly higher in a public bar when consuming beer while talking with friends compared to not having friends around.

The bus stop elicited a large number of negative emotions in preliminary trials carried out in this study to document the emotions elicited by this environment. This study further revealed that negative emotions of being unable to concentrate, uncertain about things, negative, tired, tense, unhappy, annoyed and anxious were rated significantly higher in the bus stop compared to the laboratory, university study area and café environments after consuming chocolate ice cream. Ulrich et al. (1991) reported that aggression was significantly increased in a traffic environment as compared to a pedestrian mall. Paunović et al. (2014) further reported that public transport noise during the day elicited higher levels of annoyance than people in areas without public transport noise.

Emotions evoked in the four different environments might be related to the varying affective dimensions of the different environments. The university study area and café environments were found in this study to be more pleasant and were linked to positive emotions. Negative emotions on the other hand were related to the least pleasant environment, that is, the bus stop. In addition, the laboratory was found to elicit a reduced range of emotions compared to the other three environments.

4.4. Different eating environments correlated with different emotions

Environmental factors can influence emotions. Barrett, Mesquita, Ochsner, and Gross (2007) demonstrated that emotions were not just influenced by the stimulus itself, but were also influenced by psychosocial factors. In this study, the laboratory was only correlated to the emotion of concentrating. On the other hand, the cafe and university study area environments were rated as the most pleasant, and were

correlated to more positive emotions after consuming chocolate ice cream. The university study area environment was associated with the positive emotions of calm, excited, and at ease. The café was further correlated to positive emotions of joy, happy, pleasure, cheerful, positive and satisfied. Kim and Moon (2009) found that the ambience, aesthetics, layout, electric equipment, and seating comfort of theme restaurants in Alberta and Canada had significantly increased positive emotions. Jang and Ryu (2007) similarly reported that the aesthetics and ambience of high-class restaurants had significant effects on the following emotions: happy, pleased, entertained, and delighted.

On the other hand, the bus stop was found to be the least pleasant and was correlated to more negative emotions including tense, tired, negative, anxious, annoyed, unhappy, unable to concentrate, and uncertain about things. Urban and Máca (2013) found that listening to road and railway noises evoked the negative emotion of annoyance due to noise that had a negative effect on participants' satisfaction.

4.5. Relationship between perception and emotional responses in different eating environments

Emotional feelings can affect perception (Danner et al., 2016; Jaeger, Spinelli, Ares, & Monteleone, 2018; Köster & Mojet, 2015). In this study, only the positive emotion of concentrating was related to creamy flavour in the laboratory environment. This may be because the laboratory constitutes a controlled environment (Kozłowska et al., 2003), and participants were much more likely to concentrate in this environment and consequently it did not evoke as many emotions as the other environments.

The present results further provide support for the role of emotional valence of stimuli in mediating crossmodal correspondences between eating environments and flavour perception. The negative emotions of tense, tired, anxious, negative, annoyed, unable to concentrate, unhappy and uncertain about things were associated with bitter and roasted flavours in the bus stop. Similarly, some studies have shown that negative emotions are associated with bitter taste. Kantono, Hamid, Shepherd, Yoo, et al. (2016) demonstrated that the negative emotions of disgust, contempt and disappointment were related to bitterness when consuming gelato while exposed to disliked music. Likewise, Jager et al. (2014) showed that the negative emotions of boredom and aggression were related to bitterness when consuming 70% cocoa chocolate.

In the current study, the positive emotions of happy, pleasure, joy, cheerful, positive and satisfied were associated with sweetness in the café. Studies have also reported that positive emotions are associated with sweet taste. Kantono, Hamid, Shepherd, Yoo, et al. (2016) correlated positive emotions of happiness, satisfaction to sweet taste when consuming chocolate gelato while listening to liked music. Likewise, Jager et al. (2014) demonstrated that positive emotions of interested, happy, and loving were related to the sweetness of orange and blueberry flavour chocolate. Thomson, Crocker, and Marketo (2010) also reported that positive emotions of fun and easy-going were related to the sweetness of chocolate.

Interestingly, it was also found that the positive emotions of relaxation and excitement were related to milkiness in the university study area environment. Similarly, Kantono et al. (2018) showed that positive emotions of amusement, enjoyment, love, happiness, and satisfaction were related to milkiness when consuming gelato while listening to music differing in pleasantness. In addition, positive emotions of calm, at ease and excited were associated with cocoa flavour in the university study area environment. No studies have reported the association between the positive emotions like calm, at ease and excited, and cocoa flavour. Only Thomson et al. (2010) reported that positive emotions of energetic and powerful were related to cocoa flavour when consuming dark chocolate in the laboratory.

Based on the data reported here, it was found that valence dimensions of the real eating environments affected both emotions and perceptions more than the controlled laboratory environment. Pleasant environments (café, university study area) resulted in positive emotions that are related to sweet, cocoa and milkiness. The least pleasant environment (bus stop) resulted in negative emotions related to bitter and roasted flavours.

4.6. Consuming ice cream in different eating environments influenced electrophysiological responses

After consuming chocolate ice cream, SC was significantly higher in the university study area, café, and bus stop as compared to the laboratory. In this study, the sharpness and roughness of bus stop and café environments were higher than the laboratory. The sensory pleasantness of participants decreased with the increase in sharpness, loudness and roughness of sounds as stated in the Zwicker's model of psychoacoustics and sensory pleasantness (Fastl & Zwicker, 2007). Parsons, Tassinary, Ulrich, Hebl, and Grossman-Alexander (1998) reported that SC of participants significantly increased in an unpleasant urban roadside environment as compared to the forest roadside environment. Alvarsson et al. (2010) further reported that their participants' SC increased significantly in unpleasant high noise condition compared to the nature sound condition. The reason as to why SC was increased may be due to the increase of mental stress when listening to noise (Sun et al., 2010).

HR was significantly decreased in the university study area compared to the bus stop after consuming chocolate ice cream. Zhai and Barreto (2006) reported that HR increased when people were under stress. Studies have shown that HR can be significantly influenced by the environment. Laumann, Gärling, and Stormark (2003) reported that the HR of participants significantly decreased when watching videos on nature films compared to urban environments. Meanwhile, Labbé, Schmidt, Babin, and Pharr (2007) showed that the HR of participants significantly decreased under the self-selecting relaxing and classical music conditions, as compared to the heavy metal music conditions following a stressor.

5. Conclusion

This study set out to determine how emotions and electrophysiological measures influenced temporal changes in the perception of the flavour of chocolate ice cream consumed in different eating environments. The dominant flavour attributes of ice cream were found to vary in different environments, in particular, covarying with affective dimensions, emotions and electrophysiological measures. Consumption of ice cream in the different eating environments influenced temporal changes in flavour, the emotions evoked, and electrophysiological measures. Valence dimensions measured in real eating environments affected both emotions and perceptions more than in the laboratory environment. Eating ice cream in different eating environments also resulted in significant changes in SC and HR. The results of this research support the notion that emotion, measured both by self-report and electrophysiologically, influenced temporal changes in flavour perception of chocolate ice cream when consumed in the different environments. This research contributes additional evidence that suggests the importance of considering electrophysiological measurements of participants while eating to explain changes in perception of food. Further research can further explore how different eating contexts can influence the flavour perception, emotions and electrophysiological measures obtained when consuming more complex foods (e.g., fried chicken and pizza). The findings reported in the present study revealed that that eating environment can give rise to changes in the temporal dynamics of multisensory flavour perception in the case of ice cream.

Such results may have important marketing implications for the marketing of food as multisensory experiences in real eating environments can be manipulated to provide stimulants that can improve the perception of the flavour of food without necessarily changing the flavour of food itself. The current study goes some way towards enhancing our understanding on how environments in which food is consumed affect perception. In addition, further studies can focus on the control for emotional state which should prior to entering eating context (e.g. going to a café to relax, or study space to study already stressed). This information can be used to develop targeted interventions aimed at improving perception of food in real-world eating environments.

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