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

by

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Abstract

The eating context is becoming an increasingly important area of research as it influences eating behaviour and hedonic perception of food. This study investigated temporal flavour changes of chocolate ice cream consumed in the laboratory, café, university study area and bus stop environments, and how emotion and electrophysiological measurements were influenced. The temporal dominance of sensations (TDS) method was used to analyse the dominance rate of flavour perception in different environments after consuming ice cream. The emotional responses of participants were measured using the check-all-that-apply (CATA) list of emotions particularly developed for this study in the different environments after consuming ice cream. Electrophysiological measurements of heart rate (HR), blood volume pulse (BVP) and skin conductance (SC) were also determined. TDS results revealed significant differences between the dominant flavour perceptions of ice cream in the different environments. Canonical variate analysis (CVA) further demonstrated the relationship between flavour perception and frequencies of emotion responses when ice cream was consumed in different eating environments. The standardized duration of flavour perception ($p < 0.05$) and the frequencies of emotional responses ($p < 0.001$) showed significant difference between the different eating environments using the Hotelling-Lawley MANOVA analysis. The café environment was correlated with most of the positive emotions and sweet flavour. The university study area environment was correlated with positive and negative emotions, and cocoa and milky flavours. The bus stop environment was correlated with most of the negative emotions, and roasted and bitter flavours. The laboratory environment was correlated with the concentrating attribute and creamy flavour. SC was significantly increased in the university study area compared to the laboratory environment ($p < 0.05$), and HR was significantly decreased in the university study area environment compared to the bus stop environment ($p < 0.05$). The evidence from this study indicates that the eating environments is an important factor to consider when carrying out sensory testing as emotions, sensory perception, electrophysiological responses of participants are all influenced differently when food is consumed in different environments.

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Abbreviations

TDS temporal dominance of sensations

CATA check-all-that-apply

HR heart rate

SC skin conductance

BVP blood volume pulse

CVA Canonical variate analysis

Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, 'changes in flavour, emotion and electrophysiological measurements when consuming chocolate ice cream in different eating environments' contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

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Chapter 1 Introduction

Sensory testing of food is often carried out in a laboratory to accurately analyse attributes of sensory products (Pound et al., 2000). However, in reality, consumers eat foods in different environments instead of a laboratory environment. Different eating environments can influence food perceptions (Hersleth et al., 2005; Kim et al., 2016). Studies have shown that consuming food in central locations (Pound et al., 2000; Hersleth et al., 2003; Petit et al., 2007), home (Pound et al., 2000; Kozlowska et al., 2003; Zhang et al., 2017, Daillant-Spinnler et al., 2005) and immersive (Bangcuyo et al., 2015; Hathaway et al., 2017) environments resulted in significantly higher hedonic ratings than the control laboratory environment.

Temporal Dominance of Sensation (TDS) can describe the changes in dominant sensory attributes over a specified time (Pineau et al., 2012). TDS has been used to characterize a variety of chocolate products including different kinds of chocolate (Jager et al., 2014) and chocolate containing different proportion of cocoa (Rodrigues et al., 2016a and Rodrigues et al., 2016b), the first dominant attribute was generally sweet, and the next dominant attributes generally being either milky or cocoa. The last dominant attribute was always bitter attribute in chocolates containing more cocoa (between 55 – 85% cocoa). In addition, few studies have further shown that changes in the dominant attributes of food can also occur when listening to music varying in valence. Sweet and bitter varied in dominance at the start mastication period when listening to silent, neutral, liked music and disliked music after consuming bittersweet chocolate gelato (Kantono et al., 2016a; Kantono et al., 2018).

The emotion of consumers can be influenced under different consumption environments due to lighting, background music, spatial layout and temperature (Heung and Gu, 2012). Recent, studies have shown that restaurant atmospherics have a significant effect on emotions of consumers in terms of positive emotions (Prayag et al., 2014; Jang and Namkung, 2009; Jang and Jeong, 2011; Jang et al., 2011), arousal (Hyun et al., 2014; Jang and Ryu, 2007) and pleasure (Kim and Moon, 2009). However, the effects of consuming food in real eating environments and laboratory environment in terms of emotions perceived by consumers have not been researched much. Danner et al. (2016) showed that positive emotions were rated significantly higher in the restaurant environment after consuming wine compared to home and laboratory conditions, attributing it to participants having social interactions in the restaurant. Furthermore, Schouteten et al. (2017) reported that positive emotions were rated significantly higher at home when consuming yogurt compared to the sensory laboratory environment Dorado et al. (2016) further demonstrated that positive emotions of participants were significantly increased and negative emotions of participants were significantly decreased when drinking beer in central locations with freely-elicited scenario (i.e. talking with friends) compared to the control environment.

Electrophysiological measurements are important to monitor during food consumption, as it can recognize the food-related reaction and emotion directly related to consumption (Nijs et al., 2010). Studies to date have investigated how environment or food consumption affected electrophysiological measures like systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR) and skin conductance (SC). Noisy environments like those near the public transport were reported to generally increase blood pressure (Paunovic et al., 2013; Dratva et al., 2012; Kjellgren et al., 2010; Belojevic et al., 2008), HR (Belojevic et al., 2008) and SC (Alvarsson et al., 2010). Environments near the grocery stores (Dubowitz et al., 2012) and high walkable neighborhoods (Li et al., 2009; Dubowitz et al., 2012) significantly decreased SBP and DBP.

Studies have shown that different environments can affect hedonic perception, emotions and electrophysiological responses. Hence, the objective of this study is to determine how temporal flavour perception, consumer emotion and electrophysiological measurements are influenced in the laboratory and real environments when consuming chocolate ice cream.

Chapter 2 Literature Review

2.1 Sensory perception of food in different eating environment

Sensory testing of food perception is often carried out in a laboratory. The advantage of doing sensory testing in the laboratory is that participants can be more critical of the food attributes, and therefore provide better description and discrimination of food characteristics (Kim et al., 2016). However, doing sensory testing in the laboratory might not show the real food liking of participants due to being controlled, while real environments could make participants feel less different compared to their daily when doing sensory testing (Kim et al., 2016; Pound et al., 2000). One of the limitations of carrying out sensory testing in real environments however is that it is hard to control the settings of a real environment, which can lead to some unreliable results of sensory evaluation (Petit et al., 2017). Another disadvantage is that doing sensory testing in real environments involves more time and more money compared to carrying out testing in a laboratory, and is much harder to set up (Meiselman et al., 2000).

Recently, some researches have published studies to demonstrate the impact of environment on food perception in terms of hedonic ratings (Table 2.1) and intensity of food attributes (Table 2.2).

2.1.1 The impact of environment on overall liking of food

Table 2.1 shows that the hedonic ratings of food can be different when consumed under different environments (Mendes et al., 2001; Ryu and Jang, 2007). Studies have demonstrated that the hedonic ratings of food when consumed at home is higher than under controlled laboratory conditions. A study by Kozlowska et al. (2003) pointed out that the apple juice without sucrose addition when consumed by young adults was significantly liked at home compared to laboratory and university common room environments. Similarly, Daillant-Spinnler et al. (2005) also showed that high fat cream cheese was significantly liked when consumed at home compared to the laboratory. Likewise, Hersleth et al. (2003) found that the Chardonnay wine served with food was more liked when served in a reception room compared to the laboratory environment. Pound et al. (2000) further claimed that chocolate bars were significantly liked in commercial locations (central location) compared to the teaching laboratory. Only Petit et al. (2007) found that the water-based ice coffee was significantly liked in both the sensory and “hot” laboratory environments (by using warm colour decoration and lighting) compared to the cafeteria. The milk-based ice coffee was significantly liked in both the sensory and "hot" laboratory environments compared to the meeting room.

Sweetened protein beverages using either monk fruit extract, acesulfame potassium and sucralose, and stevia as sweetening agents were significantly liked at home compared to a central location (Zhang, 2017). In addition, regular and diet milk beverages (Boutrolle et al., 2005), salted crackers (Boutrolle et al., 2007), and sparkling water (Boutrolle et al., 2007) were reported to be more liked at home compared to a central loaction but not significantly. Sosa et al. (2008) further reported that the chocolate milk beverages were more liked but not significantly at home compared to the institute room (central location) environment (central location) with participants coming from low-income family. Boutrolle et al. (2005) stated that food perception at home to be more realistic than controlled central location environments (Boutrolle et al., 2005).

It was found that the more realistic eating environments resulted in higher hedonic rating scores. Bangcuyo et al. (2015) showed that Maxwell House, Starbucks, and Douwe Egberts coffee were significantly liked in the virtual coffee house environment with audio and visual cues compared to the traditional sensory booths condition. Another study by Hathaway et al. (2017) interestingly reported that the cookies were significantly liked under a full immersion laboratory environment (traditional booths fitted with a 48-inch LED screen) compared to traditional booths and mixed immersion environments (traditional booths fitted with a LG Flatron E2211 22-inch computer monitor and cookie aroma stimuli).

A few studies showed no significant changes with consumption under different environments. Kozlowska et al. (2003) identified that the hedonic rating of apple juice without sucrose addition when consumed by elderly had no significant difference between home, laboratory and university common room environments. They also reported no significant changes in hedonic ratings of apple juice with 2, 4, 7, 10% sucrose addition when consumed by elderly between home, laboratory and university common rom respectively. This could be due to the fact that elderly people were less sensitive to sugar and had difficulties in carrying out tasks (Kozlowska et al., 2003). Similarly, Pound et al. (2000) reported that the hedonic ratings of chocolate bars were not significantly different between home, sensory laboratory and central location environments. Moreover, Hersleth et al. (2005) showed that the hedonic ratings for the same cheese in laboratory, home and central location environments were relatively similar. They concluded that no significant difference was found due to the testers' degree of familiarity with the brand of cheese used in their study.

From the studies reviewed, it is evident that food consumed at home had higher overall liking ratings compared to central location (Boutrolle et al., 2005; Boutrolle et al., 2007; Sosa et al., 2008; Zhang, 2017) and laboratory (Kozlowska et al., 2003; Daillant-Spinnler et al., 2005) environments. Food consumed in central locations had significantly higher liking of Chardonnay wine (Hersleth et al., 2003) and chocolate bars (Pound et al., 2000) compared to the laboratory environment. Food consumed in the immersive laboratory environments had significantly higher liking of coffees (Bangcuyo et al., 2015) and cookies (Hathaway et al., 2017) compared to the laboratory environment. Hence, the eating environment where food is consumed is an increasingly important factor to consider when carrying out sensory testing, However, Hersleth et al. (2005) reported that one of the limitations of doing sensory testing in the real environments is the fact that factors like temperature and sounds are hard to control.

Table 2.1 The impact of eating environment on food liking

Food	Location	Method	Finding	Reference
Apple juice (0, 2, 4, 7,10% addition)	Laboratory Home University common room	nine-point hedonic scale	Apple juice without sucrose addition when consumed by young adults was significantly liked when consuming at home compared to laboratory and university common room environments.	Kozlowska et al., 2003
Milk chocolate bars	Home Sensory laboratory Teaching laboratory Central location (commercial locations around Palmerston North, New Zealand)	nine-point hedonic scale	The chocolate bars were significantly liked when consumed in commercial locations (central location) compared to the teaching laboratory.	Pound et al., 2000
Chocolate milk	Home Institute room (Central location)	ten-point hedonic scale	The milk beverages were more liked but not significantly when consumed at home compared to a central location with participants coming from low-income family.	Sosa et al., 2008
Protein beverages	Home Testing room (Central location)	nine-point hedonic scale	The protein beverages were significantly liked when consumed at home compared to central location.	Zhang, 2017
Two milk beverages (Regular and diet version with low sugar and fat)	Home Testing room (Central location)	ten-point hedonic scale	The regular and diet milk beverages were more liked but not significantly when consumed at home compared to central location.	Boutrolle et al., 2005

Cream cheese (low-, medium- and high–fat)	Laboratory Home	10-cm hedonic scale	Only the high fat cream cheese was significantly liked when consumed at home compared to the laboratory.	Daillant-Spinnler et al., 2005
Cheese (six kinds of commercial Norwegian market cheeses)	Laboratory Home Central location (club house)	nine-point hedonic scale	The hedonic ratings for the same cheese in laboratory, home and central location were relatively similar.	Hersleth et al., 2005
Fermented milk (regular and diet version with low sugar and fat), salted crackers (national brand and private brand) Sparkling water (brand A and brand B)	Home Testing room (Central location)	ten-point hedonic scale	The salted crackers (national brand and private brand) and sparkling water (brand A and brand B) were more liked but not significantly when consumed at home compared to the central location.	Boutrolle et al., 2007
Chardonnay wine (served with food and without food)	Laboratory Reception room	nine-point hedonic scale	The Chardonnay wine served with food was more liked when consumed in a reception room compared to the laboratory environment.	Hersleth et al., 2003
Coffee (Maxwell House, Starbucks, Douwe Egberts)	Traditional sensory booths Virtual coffee house with audio and visual cues and combining with cinnamon roll aroma stimulation	nine-point hedonic scale	Maxwell House, Starbucks, and Douwe Egberts coffee were significantly liked when consumed in the virtual coffee house condition compared to the traditional sensory booths condition within 1-month hiatus.	Bangcuyo et al., 2015
Cookie	Traditional booths Mixed immersion (including traditional booths with visual (a LG Flatron E2211 22-inch	nine-point hedonic scale	The cookie was significantly liked when under the full immersion booths compared to traditional booths and mixed	Hathaway et al., 2017

	computer monitor) with the same cookie aroma stimuli Full immersion (including traditional booths and immersion with nine 48-inch LED screen) with the same cookie aroma stimuli		immersion with the same cookie aroma stimuli.	
Water-based iced coffee Milk-based iced coffee	Meeting room Cafeteria Normal laboratory Laboratory in "hot" environment (by using warm colour decoration and lighting)	twenty-point hedonic scale	The water-based ice coffee was significantly liked when drinking in the normal laboratory compared to cafeteria. The milk-based ice coffee was significantly liked when drinking in the normal laboratory compared to the meeting room, and in the cafeteria compared to the meeting room.	Petit et al., 2007

2.1.2 The liking of food attributes in different eating environments

Different environments can also influence liking of flavour attributes of food. A study by Sosa et al. (2008) stated that the appearance and flavour of chocolate milk were significantly liked at home compared to the institute room (central location). Meiselman et al. (2000) also reported that the food acceptance ratings of flavour, texture and colour of chocolate mousse were higher in the training restaurant compared to the dining hall. Furthermore, Petit et al. (2007) claimed that the frequencies of bitter attribute of water-based iced coffee were higher in the meeting room compared to the laboratory environment. The frequencies of too much sugar and strong coffee taste attributes of water-based iced coffee were higher in the cafeteria compared to the laboratory environment. The frequencies of creamy and milk taste attributes of milk-based coffee were higher in the meeting room compared to the laboratory environment. The frequencies of refreshing, sweet taste and thick attributes of milk-based coffee were higher in the cafeteria compared to the laboratory environment. However, this study only used the frequencies of flavour attributes to show the difference of flavour attributes in the different environments instead of using methods like ANOVA analysis.

In addition, Zhang (2017) found that the liking scores of aroma, flavour, sweetness, milky flavour, vanilla flavour, thickness and aftertaste attributes of protein beverage with acesulfame potassium and sucralose addition were significantly higher in the testing room (central location) environment compared to home. The liking scores of appearance of protein beverages with acesulfame potassium, stevia and sucralose addition and fructose and stevia addition were significantly higher at home compared to the testing room. The liking scores of aroma, sweetness, milky, vanilla, thickness and aftertaste attributes of protein beverages with acesulfame potassium and sucralose addition were significantly higher at home compared to the testing room.

Interestingly, only Pound et al. (2000) reported that liking of colour, hardness, melting feeling and chocolate flavour of chocolate had no significant difference between the central location, home, sensory and teaching lab environments. This may because the consuming time of this experiment was not during meal times, which was not consistent with the other experiments done by authors such as the overall liking, intensities of flavour experiment completed during meal times (Pound et al., 2000).

In general, food consumed at home (Sosa et al., 2008; Zhang, 2017) had significantly higher liking of food attributes compared to the central location environment. Food consumed in central locations like cafeteria and meeting room (Petit et al., 2007) had higher frequencies of bitter, too much sugar, strong coffee taste, creamy, milk taste, refreshing, sweet taste and thick attributes compared to the laboratory environment.

2.1.3 The impact of eating environment on the intensity of food attributes

Only a few studies have described the impact of eating environments on the intensity of sensory attributes of food. Pound et al. (2000) found that the intensity of sweetness, chocolate flavour of chocolate bars significantly increased in the central location and home environments compared to the sensory laboratory. The smoothness intensity of chocolate bars significantly increased at home compared to the sensory lab environment. The colour intensity of chocolate bars significantly increased at home compared to the teaching laboratory. The melting intensity of chocolate bars significantly increased in the central location environment compared to the sensory laboratory.

A noisy environment had a significant effect on taste compared to a quiet environment. Rahne et al. (2018) showed that the sweet taste of sucrose significantly increased and sour taste of citric acid significantly decreased in the noisy aircraft cabin with normal and hypobaric pressure conditions compared to quiet aircraft cabin with normal and hypobaric pressure conditions. However, no significant difference in bitter and salty was found in the different environments. Stafford et al. (2012) also reported that the sweet taste of alcohol significantly increased when listening to music compared to the quiet condition. On the other hand, Woods et al. (2011) reported that the sweetness and saltness of commercially available sweet and savoury foods were significantly decreased when listening to loud sound compared to quiet sound.

Again, similar to the liking of food attributes, food consumed at home (Pound et al., 2000) had significant higher intensity of sensory attributes compared to the sensory laboratory. Food consumed in central locations (Pound et al., 2000) also had significantly higher intensity of food attributes compared to sensory laboratory. In addition, noise in the eating environment (Rahne et al., 2018; Stafford et al., 2012) was shown influence of sweetness. Hence, more research in this area is necessary to determine how eating environment can change sensory perception of food.

Table 2.2 The impact of eating environment on food attributes

Food	Location	Method	Attribute	Finding	Reference
Milk chocolate bars	Home Sensory laboratory Teaching laboratory Central location (commercial locations around Palmerston North, New Zealand)	nine-point hedonic scale (liking of colour) seven-point hedonic scale (liking of hardness, melting and chocolate flavour) Five-point just - right scale (the intensity of colour and melting) 10cm line scale (intensity of hardness and smoothness) Seven-point category scale	Colour Hardness Melting Chocolate flavour Sweetness Smoothness	The colour, hardness, melting feeling and chocolate flavour of chocolate were not significantly different when consumed in the central location, home, sensory and teaching laboratory environments. The colour intensity of chocolate bars significantly increased with consumption at home compared to the teaching laboratory. The smoothness intensity of chocolate bars significantly increased with consumption at home compared to sensory laboratory. The melting intensity of chocolate bars significantly decreased with consumption in a central location environment compared to the sensory and teaching laboratory environments. The chocolate flavour intensity of chocolate bars significantly decreased with consumption in the sensory laboratory	Pound et al., 2000

				compared to the central location, home and teaching lab environments. The sweetness intensity of chocolate bars significantly decreased with consumption in the sensory laboratory compared to the central location and home environments.	
Chocolate milk	Home Institute room (Central location)	ten-point hedonic scale	Appearance Flavour	The appearance and flavour of chocolate milk were significantly liked with consumption at home compared to the central location environment.	Sosa et al., 2008
Water-based iced coffee Milk-based iced coffee	Meeting room Cafeteria Laboratory Laboratory with “hot” environment (by using warm colour decoration and lighting)	twenty-point hedonic scale	Water-based: Refreshing Bitter Too much sugar Strong coffee taste Milk-based: Too much sugar Refreshing Creamy Strong coffee taste Sweet taste Thick	The frequencies of bitter attribute of water-based iced coffee were higher in the meeting room compared to the laboratory environment. The frequencies of too much sugar and strong coffee taste attributes of water-based iced coffee were higher in the cafeteria compared to the laboratory environment. The frequencies of creamy and milk taste attributes of milk-based coffee were higher in the meeting room compared to the laboratory environment. The	Petit et al., 2007

				frequencies of refreshing, sweet taste and thick attributes of milk-based coffee were higher in the cafeteria compared to the laboratory environment.	
Protein beverages	Home Testing room (Central location)	nine-point hedonic scale	Aroma Flavour Sweetness Milky Vanilla Thickness Aftertaste	The liking scores of flavour, sweetness, milky, vanilla, thickness and aftertaste of protein beverage with acesulfame potassium and sucralose addition were significantly the highest with consumption in the central location environment. The liking scores for appearance of protein beverages with acesulfame potassium, stevia and sucralose addition and fructose and stevia addition were significantly the highest with consumption at home. The liking scores of the aroma of protein beverages with acesulfame potassium and sucralose addition were significantly the highest with consumption at home. The liking scores of sweetness, flavour, milky, vanilla, thickness and aftertaste of protein beverages with	Zhang et al., 2017

				acesulfame potassium and sucralose addition were significantly the highest with consumption at home.	
Sucrose Citric acid Sodium chloride Quinine hydrochloride	Silent and noisy aircraft cabin with normal and hypobaric pressure	eighteen-point hedonic scale	Sweet taste Sour taste Salty taste Bitter taste	The sweet taste of sucrose significantly increased in the noisy aircraft cabin with normal and hypobaric pressure conditions compared to quiet aircraft cabin with normal and hypobaric pressure conditions. The sour taste of citric acid significantly decreased in the noisy aircraft cabin with normal and hypobaric pressure conditions compared to quiet aircraft cabin with normal and hypobaric pressure conditions. The bitter taste of quinine hydrochloride and the salty taste of sodium chloride had no significant difference between the quiet and noisy aircraft cabin with normal and hypobaric pressure conditions.	Rahne et al., 2018
Dessert	Dining hall Training restaurant	seven-point hedonic scale	Flavour Texture colour	The food acceptance rating of flavour, texture and colour of dessert were significantly higher with consumption of dessert in the training restaurant compared to the dining hall.	Meiselman et al., 2000

2.2 Temporal Dominance of Sensation (TDS) analysis of chocolate product attributes

The Temporal Dominance of Sensation (TDS) method can be used to understand the temporal evolution of dominant sensory attributes with time. The different food attributes can be distinguished by analyzing the peak point of TDS curves at different time periods.

TDS analysis of chocolate samples containing a high percentage of cocoa (70%, 85%) were found to be dominantly dry in the early mastication period, and bitter was dominant towards the end of mastication period (Jager et al., 2014). However, the TDS analysis of flavoured chocolate (blueberry and orange) were found to be dominantly fruity at the beginning of the mastication period, and sweet was dominant for a long dominance until the end of the mastication period. In other studies, sweet was always the first dominant attribute in chocolate and chocolate bars containing a low percentage of cocoa of between 28 – 41% (Rodrigues et al., 2016a; Rodrigues et al., 2016b). On the other hand, chocolate bars containing a higher percentage of cocoa (55%, 70%) showed that bitter was the dominant attribute from the beginning until the end of the mastication period. In addition, with chocolate bars containing 85% cocoa, cocoa was the dominant attribute from the beginning until the final stage of the evaluation period. These studies only reported that temporal changes in dominance of flavours in chocolate varying in flavours and cocoa content.

Recently, studies have shown that changes in the dominant attributes of food can also occur when listening to music that differed in pleasantness or liking. Kantono et al. (2016a) reported that bitter was dominant at the start of mastication when listening to disliked music after consuming bittersweet chocolate gelato. Kantono et al. (2018) further reported that sweet was always the first dominant attribute at the early beginning of the mastication when listening to silent, neutral, liked and disliked music after consuming bittersweet chocolate gelato. The authors reported that the change in flavour might be attributed to emotions experienced by participants. Hence, the next section of this review will discuss how emotions can influence sensory perceptions.

2.3 The relationship between emotions and flavour perception

The relationship between food flavour perception and emotions of consumers have been investigated in the last eight year. In general, positive emotions were related to sweet when consuming chocolate (Thomson et al., 2010; Jager et al., 2014), and chocolate gelato (Kantono et al., 2016a). On the other hand, negative emotions were related to bitter taste when consuming chocolate (Thomson et al., 2010), and chocolate gelato (Kantono et al., 2016a). In addition, cocoa was related to both positive and negative emotions when consuming chocolate (Thomson et al., 2010).

Studies have reported that positive emotions were related to sweet taste. Thomson et al. (2010) showed that positive emotions (i.e. fun, easy-going) were related to sweet taste of chocolate. Kantono et al. (2016a) also indicated that positive emotions of happiness and satisfaction were related to sweetness of chocolate gelato when listening to liked music. Similarly, Jager et al. (2014) reported that positive emotions of interested, happy and loving were related to sweetness of orange and blueberry flavour chocolate. Furthermore, Thomson et al. (2010) reported that positive emotions of energetic and powerful and negative emotion of aggressive were related to cocoa taste of chocolate.

On the other hand, many studies demonstrated that negative emotions are associated with bitter taste. Jager et al. (2014) reported that negative emotions (i.e. bored, aggressive) were related to bitter taste when consuming chocolate containing 70% cocoa. Likewise, Kantono et al. (2016) indicated that negative emotions (i.e. disgust, contempt and disappointment) were related to bitter taste when consuming bittersweet chocolate gelato under disliked music condition.

2.4 The impact of environment on consumer emotion responses

Food quality is not the only reason that influences consumer emotion when consuming food. Consumer emotion can also be influenced by the consumption environment (Edwards et al., 2008). The interior decor, ambient atmosphere and spatial layout are three main environmental factors, which influence consumer emotion (Han and Ryu, 2009). In addition, a positive consumption environment can result in consumers experiencing positive emotions (Lin, 2004). The positive emotions in turn had a significant effect on consumer behavioural intentions as well. Researchers have reported the effect of environment on consumer emotions. These studies are summarized in Table 2.3.

Hyun et al. (2014) investigated the effect of spatial layout, ambient conditions and décor and artifacts of 379 luxury restaurants in United States on the arousal of customers. The spatial layout, ambient conditions and décor, artifacts and food quality of luxury restaurant had significant effects on the arousal of customers. Arousal had a significantly positive effect on pleasure that in turn had a positive effect on behavioural intentions of customers in terms of wanting to dining out at the restaurant again, and recommending and saying positive things about the restaurant to other. Similarly, Prayag et al. (2014) also showed that the restaurant atmospherics (pleasant décor, cleanliness of dining area and bathroom, comfort of dining area, temperature of dining area, music quality, aromas and scents in the establishment, adequacy of the colour scheme, lighting effects and authenticity of the atmosphere) and food quality of the restaurants in French Riviera had a significantly positive effect on the positive emotions of consumers in terms of relaxation, pleasure and excitement. The positive emotions in turn had a significant effect on behavioural intentions in terms of wanting to dine out at the restaurant again, and recommending the restaurant to others. In addition, Jang and Namkung (2009) reported that the atmospherics of the full-service restaurant had a significant effect on positive emotion (i.e. joy, excitement, peacefulness, refreshment) of 40 participants from a mid-western university in the U.S. The atmospherics of restaurant had no significant effects on negative emotion. The positive emotions in turn had a significant effect on behavioural intentions in terms of wanting to dine out at the restaurant again, and recommending and saying positive things about the restaurant to others. Kim and Moon (2009）found that the ambient condition, facility aesthetics, layout, electric equipment, and seating comfort of theme restaurants in Alberta and Canada had significant effects on pleasure (i.e. happy, pleased, entertained, delighted) that in turn affected revisiting intention of 208 participants.

Jang and Ryu (2007) found that the facility aesthetic, and the high quality ambience of upscale restaurants had significant effects on pleasure of participants in the U.S. The ambience of upscale restaurants had a significant effect on arousal. Pleasure (happy, pleased, entertained and delighted) and arousal (cheerful, excited and surprised) had significant effects on behavioral intentions (patronage, staying longer, spending more and recommendation). This is consistent with the study of Jang and Jeong (2011), who demonstrated that the restaurant atmosphere (cleaning dining area and appealing interior design) had a significant effect on positive feelings of 201 participants from midwestern university in the U.S. Moreover, Jang et al. (2011) also reported that the authentic atmospherics Chinese style of a mid-scale level Chinese restaurant had a significant effect on positive emotions of pleasure, excitement, contentment, refreshment, interest and relaxation of participants in a mid-western city in U.S that in turn affected behavioural intentions (i.e. repeated purchasing, positive word-of-mouth, recommendation). The authentic atmospherics of mid-scale level Chinese restaurant however had a significant effect on negative emotions that had significant negative effects on behavioural intentions.

Studies also compared the effects of consuming food in real eating environments and the laboratory on emotions perceived by consumers. Danner et al. (2016) reported that positive emotions of energetic, happy and loving were rated significantly higher in the restaurant environment after consuming wine compared to home and laboratory environments. They attributed it to participants talking more and having social interactions in the restaurant compared to the sensory laboratory. In addition, Schouteten et al. (2017) reported that positive emotions of interested, pleasant and satisfied were rated significantly higher at home when consuming yogurt compared to the sensory laboratory. It was further demonstrated by Dorado et al. (2016) that the positive emotion of exciting was significantly higher in a pub (central location) with freely-elicited scenario (i.e. talking with friends) compared to the control environment when consuming beer. In addition, negative emotions of disgusted, shocked and disconfirmed were significantly decreased in in the pub compared to the control.

In summary, most studies have shown that restaurant atmospherics have a significant effect on emotions of consumers in terms of positive emotions (Prayag et al., 2014; Jang and Namkung, 2009; Jang and Jeong, 2011; Jang et al., 2011), arousal (Hyun et al., 2014; Jang and Ryu, 2007) and pleasure (Kim and Moon, 2009). These emotions also significantly influenced behavioural intentions of consumers. Only few studies reported that positive emotions were rated significantly higher when consuming food in real eating environments like in restaurant

(Danner et al., 2016), and home (Schouteten et al., 2017) environments compared to laboratory. Hence, it is imperative to investigate how consumer emotions are influenced as this will influence how food will be perceived when eaten in different environments.

Table 2.3 The impact of eating environment on emotions

Consumption environment	Method	Emotion attribute	Finding	Reference
Luxury restaurant	five-point likert type scale	Pleasure Arousal Behavioral intentions	The spatial layout, ambient conditions and décor, and artifacts of luxury restaurant had significant effects on the arousal of customers. Arousal had a significantly positive effect on pleasure that in turn had a positive effect on behavioral intentions.	Hyun et al., 2014
Restaurant	seven-point scale	Emotion Behavioral intentions	The restaurant atmospherics (pleasant décor, cleanliness of dining area and bathroom, comfort of dining area, temperature of dining area, music quality, aromas and scents in the establishment, adequacy of the colour scheme, lighting effects and authenticity of the atmosphere) of the French restaurant had a significantly positive effect on the positive emotions of consumers in	Prayag et al., 2014

			terms of relaxation, pleasure and excitement. The positive emotion had a significant effect on behavioral intentions.	
Restaurant	seven-point scale	Positive emotion Negative emotion Behavioral intentions	The atmospherics of restaurant had a significant effect on positive emotion. The positive emotion and atmospherics had significant effects on behavioral intentions.	Jang and Namkung, 2009
Theme restaurant	seven-point scale	Pleasuring feeling Revisit intentions	The ambient condition, facility aesthetics, layout, electric equipment, and seating comfort of a restaurant had significant effects on pleasure effect and revisiting intention. The pleasure feeling had a significant effect on revisiting intentions.	Kim and Moon, 2009
Upscale restaurant	seven-point scale	Pleasure Arousal Behavioral intentions	The facility aesthetic and ambience of the restaurant had significant effects on pleasure. The ambience of restaurant had a significant effect on arousal. Pleasure and arousal had significant	Jang and Ryu, 2007

			effects on behavioral intentions.	
Restaurant	seven-point scale	Positive feelings	The restaurant atmosphere (cleaning dining area and appealing interior design) had a significant effect on positive feelings.	Jang and Jeong, 2011
Chinese restaurant	seven-point scale	Positive emotion Negative emotion Behavioral intentions	The authentic atmospherics of a Chinese restaurant had a significant effect on positive emotions. The authentic atmospherics of Chinese restaurant had a significant effect on negative emotions. The positive and negative emotions had significantly positive and negative effects on behavioral intentions respectively.	Jang et al., 2011

2.5 Electrophysiological measures

Wioleta (2013) reported that the physiological signals like blood volume pulse (BVP), blood pressure (BP), skin conductance (SC) and heart rate (HR) are useful in analysing participants' emotions. Emotions can be evaluated according to spontaneous body condition. The measures of autonomic nervous system (ANS) activity can control the organ functions by regulating parasympathetic (relaxation) and sympathetic (activation) branches, which can influence and reflect emotional responses (Kreibig, 2010). Cognitive and emotional stimulation can lead to the physiological response which can involve arousal of the sympathetic nervous system and cancellation of the parasympathetic nervous system (Mackersie et al., 2016).

2.5.1 The impact of environment on electrophysiological measures

Different environments can influence electrophysiological measures such as systolic blood pressure, diastolic blood pressure, heart rate and skin conductance. These studies are summarized in Table 2.4.

2.5.1.1 The impact of environment on Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP)

Some reports demonstrate that neighbourhood socioeconomic conditions, density of fast food stores, and proximity of grocery stores to residential areas had some effects on human SBP and DBP. Dubowitz et al. (2012) demonstrated that SBP and DBP of women only significantly decreased in the participants' residences with **g**rocery store within a radius at 1.5 miles, and the neighbourhood socioeconomic status in residential areas. Furthermore, Li et al. (2009) reported that the SBP and DBP of participants living in highly walkable neighbourhoods significantly decreased compared to low walkable neighbourhoods. In addition, SBP and DBP of participants living in low walkable neighbourhoods significantly increased in residential areas with high density of fast food restaurants compared to low density. The reason why electrophysiological measures of people living in residential areas near the **g**rocery store and highly walkable neighbourhoods affected could be due to increased possibility to buy healthy food and have more social interactions with people, which can benefit health (Mujahid et al., 2008).

Public transportation noise also influenced people's DBP and SBP. Belojevic et al. (2008) showed that the SBP of children significantly increased in noisy residences and kindergartens compared to quiet residences and kindergartens. Likewise, Paunovic et al. (2013) reported that the SBP of children significantly increased in school close to public transport compared to home close to public transport. However, the DBP of children significantly decreased in school close to public transport compared to home close to public transport. Dratva et al. (2012) also reported that the SBP and DBP of participants significantly increased in railway noisy residences at night compared to day. Similarly, Kjellgren et al. (2010) pointed out that the blood pressure of participants significantly increased under railway noisy residences but both at night and morning. The reason why SBP and DBP were affected might be due to the increase of hypertension which were caused by noisy environment (Jarup et al., 2005).

2.5.1.2 The impact of environment on heart rate (HR)

Some studies have shown that different environment conditions had different effects on the heart rate (HR) of people. A study reported by Belojevic et al. (2008) showed that the HR of children significantly increased in noisy residences compared to quiet residences and kindergartens. Furthermore, Laumann et al. (2003) demonstrated that the HR of participants significantly decreased when watching natural environment on video compared to urban environment. Stansfeld (1992) reported that people who had high noise sensitivity, judged sound negatively, which can lead to increased emotion reactions. Furthermore, noise sensitivity also has an effect on human electrophysiological measures, which may lead to annoyance reactions. Shepherd et al. (2014) claimed that the HR of participants with high noise sensitivity only significantly increased under pleasant sound condition compared to low noise sensitivity. However, there was no significant difference between participants with low, medium and high noise sensitivity under unpleasant noise condition. Only, Alvarsson et al. (2010) reported that the HR of participants had no significant difference under nature sound, high noise, low noise and ambient noise.

2.5.1.3 The impact of environment on skin conductance (SC)

Only a few studies have examined the influence of environment on SC. Frith et al. (1983) reported that the SC of participants significantly increased when hearing irrelevant tones during the task performance compared to outside the task performance. This might be because the level of arousal of participants increased when hearing irrelevant tones during task performance, and participants were relaxed when hearing irrelevant tones outside the task performance. Alvarsson et al. (2010) claimed that the SC of participants significantly decreased under nature sound condition compared to high noise condition.

Table 2.4 The impact of environment on electrophysiological measures

Environment	Response	Finding	Reference
Residential areas with fast food shop within a radius at 1.5 miles Residential areas with grocery store within a radius at 1.5 miles The neighborhood socioeconomic status in residential areas	Systolic Blood Pressure (SBP) Diastolic Blood Pressure (DBP)	The Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP) of women significantly decreased in the residential areas with grocery store within a radius at 1.5 miles, and the neighborhood socioeconomic status in residential areas.	Dubowitz et al., 2012
Residential areas with low and high density of fast food restaurant High and low walkable neighbourhoods	SBP DBP	The SBP and DBP of participants living in highly walkable neighborhoods significantly decreased compared to low walkable neighborhoods The SBP and DBP of participants living with low walkable neighborhoods significantly increased in residential areas with high density of fast food restaurants compared to low density.	Li et al., 2009
Noisy residences Quiet residences Noisy kindergartens Quiet kindergartens	SBP DBP Heart Rate (HR)	The SBP of children significantly increased in noisy residences and kindergartens compared to quiet residences and kindergartens. The HR of children significantly increased in noisy residences compared to quiet residences and kindergartens.	Belojevic et al., 2008

School closed to public transport Home closes to public transport	SBP DBP	The SBP of children significantly increased in school close to public transport compared to home close to public transport. The DBP of children significantly decreased in school close to public transport compared to home close to public transport.	Paunovic et al., 2013
Watching natural environment on video Watching urban environment on video	HR	The HR of participants significantly decreased when watching natural environment on video compared to urban environment.	Laumann et al., 2003
Railway noisy residences at day and night Traffic noisy residences at day and night	SBP DBP	The SBP and DBP of participants significantly increased in railway noisy residences at night compared to day. The SBP and DBP of participants had no significant difference between traffic noisy residences at day and night.	Dratva et al., 2012
Natural environment (Karlstad Nature Park) before and after relaxation period Simulated natural environment in human performance lab before and after relaxation period	SBP DBP	The SBP of participants significantly decreased in the natural and simulated natural environment after relaxation period compared to before relaxation period.	Kjellgren et al., 2010
Hearing irrelevant tones during task performance Hearing irrelevant tones outside task performance	Skin Conductance (SC)	The skin conductance of participants significantly increased when hearing irrelevant tones during task performance compared to hearing irrelevant tones outside task performance.	Frith et al., 1983

Pleasant sound (low-, medium-, high-noise sensitivity) Unpleasant sound (low-, medium-, high-noise sensitivity)	HR	The heart rate of participants with high noise sensitivity only significantly increased under pleasant sound condition compared to low noise sensitivity.	Shepherd et al., 2014
Nature sound High noise Low noise Ambient noise	SC	The skin conductance of participants only significantly decreased under nature sound condition compared to high noise.	Alvarsson et al., 2010

2.5.2 The impact of consuming food on electrophysiological measures

2.5.2.1 The impact of consuming drinks and food on SBP and DBP

Chen et al. (2010) indicated that the SBP and DBP of 810 participants significantly decreased with the decreased intake in sucrose, glucose, fructose and a combination of sugars (10 g/day) over18 months of observation. In addition, Poppitt et al. (2002) reported that the SBP and DBP of 46 overweight participants after consuming a low-fat, complex carbohydrate diet after 6 months significantly decreased compared to overweight participants consuming a control diet (including 40% fat). Raben et al. (2002) claimed that the SBP and DBP of 41 participants who consumed artificially sweetened drinks and foods (80% artificially sweetening from drinks, 20% from solid food) significantly decreased compared to consumption of sucrose-sweetened drinks and foods (70% sucrose from drinks, 30% from solid food) after 10 weeks.

Maersk et al. (2011) showed that the SBP of 60 healthy participants significantly decreased after consuming 1L milk and diet cola compared to regular cola every day for 6 months. The DBP of participants however decreased but not significantly. A problem with using drinks however is the fact that drinks may contain other ingredients like micronutrients that may also influence the blood pressure of participants (Christian & Stewart, 2010).

2.5.2.2 The impact of consuming food on HR

De Wijk et al. (2012) indicated that the heart rate (HR) of 16 children increased but not significantly when consuming liked food compared to disliked food. Furthermore, He et al. (2017) showed that the HR of 24 female participants had no significant difference when consuming two kinds of food (sweet or savory) with same taste, similar taste and different taste. Danner et al. (2014) claimed that the HR of 81 participants had no significant difference when consuming banana juice, grapefruit juice, mixed vegetable juice, orange juice and sauerkraut juice. However, a study reported by Verastegui-Tena et al. (2017) showed that when sucrose (sweet) and quinine (bitter) were consumed, the HR of participants significantly decreased when they were informed that the solution was either sweet or bitter before consuming compared to when they wer not informed.

2.5.2.3 The impact of consuming food on SC

De Wijk et al. (2012) reported that the SC of 15 young adults significantly increased when consuming liked food compared to disliked food. However, the SC of 16 children increased but not significantly when consuming disliked food compared to liked food. Moreover, He et al. (2017) identified that the SC of 24 female participants significantly decreased when consuming two kinds of sweet with the same taste compared to two kinds of sweet with different taste. Verastegui-Tena et al. (2017) claimed that the SC of 155 participants significantly decreased when tasting the sweet solution with and without being informed that the solution was either sweet or bitter taste before consuming compared to the bitter solution. In addition, the SC of participants significantly decreased in sweetness when they were informed that the solution was sweet before consuming compared to when they were not informed. Danner et al. (2014) further showed that the SC of 81 participants significantly decreased when consuming orange juice compared to consuming grapefruit juice, mixed vegetable juice and sauerkraut juice.

Table 2.5 The impact of consuming food on electrophysiological measures

Food	Response	Finding	Reference
Sucrose, glucose, fructose and combined sugars (10 grams per day)	SBP DBP	SBP and DBP of participants significantly decreased with decreased intake of sucrose, glucose, fructose and combined sugars (10 grams per day).	Chen et al., 2010
Milk Diet cola Regular cola	SBP DBP	SBP of participants significantly decreased after consuming 1L milk and diet cola compared to regular cola every day for 6 months, while DBP decreased after consuming 1L milk and diet cola but not significantly compared to regular cola.	Maersk et al., 2011
Sucrose-sweetened drinks and foods (70% sucrose from drinks, 30% from solid food) Artificially sweetened drinks and foods (80% artificially sweetening from drinks	SBP DBP	The SBP and DBP of participants who consumed artificially sweetened drinks and foods (80% artificially sweetening from drinks, 20% from solid food) significantly decreased compared to consumption of sucrose-sweetened drinks and foods (70% sucrose from drinks, 30% from solid food).	Raben et al., 2002
Control diet (including 40% fat) Low-fat, complex carbohydrate diet	SBP DBP	The SBP and DBP of overweight participants after consuming a control diet (including 40% fat) significantly increased compared to overweight participants consuming a low-fat, complex carbohydrate diet.	Poppitt et al., 2002
Liked food Disliked food	HR SC	The HR of children increased but not significantly when consuming liked food compared to disliked food. The SC of young adults significantly increased when	De Wijk et al., 2012

		consuming liked food compared to disliked food, but not significantly for children.	
Sucrose Quinine	HR SC	The HR of participants significantly decreased when participants were informed that solutions were either sweet or bitter compared to bot being informed. The SC of participants significantly decreased when tasting the sweet solution with and without being informed on whether it was sweet or bitter taste but not for bitter solution.	Verastegui-Tena et al., 2017
Two kinds of sweet with same taste Two kinds of sweet with different taste	SC	The SC of female participants significantly decreased when consuming two kinds of sweet with same taste compared to two kinds of sweet with different taste.	He et al., 2017
Orange juice Grapefruit juice Mixed vegetable juice Sauekraut juice	SC	The SC of participants significantly decreased when consuming orange juice compared to grapefruit juice, mixed vegetable juice and sauerkraut juice.	Danner et al., 2014

2.6 Research gap and objective

Previous studies have primarily concentrated on the impact of eating environment on food hedonic ratings (Hersleth et al., 2005; Kim et al., 2016, Pound et al., 2000; Hersleth et al., 2003; Petit et al., 2007; Kozlowska et al., 2003; Zhang et al., 2017; Daillant-Spinnler et al., 2005; Bangcuyo et al., 2015; Hathaway et al., 2017), and intensity of food attributes ((Pound et al., 2000; Rahne et al., 2018; Stafford et al., 2012).

Most studies on real environments have shown that restaurant atmospherics have a significant effect on emotions of consumers (Heung and Gu, 2012; Prayag et al., 2014; Jang and Namkung, 2009; Jang and Jeong, 2011; Jang et al., 2011; Hyun et al., 2014; Jang and Ryu, 2007; Kim and Moon, 2009). Some studies have examined that the positive and negative emotions of consumers was significantly different when eating in a laboratory compared to the real environments (Danner et al., 2016; Schouteten et al., 2017; Dorado et al., 2016). However, the impact of consumption in real environments on changes in flavour perception over time after consuming food has not been studied.

Several studies have revealed that the electrophysiological measures like blood pressure (Paunovic et al., 2013; Dratva et al., 2012; Kjellgren et al., 2010; Belojevic et al., 2008; Li et al., 2009; Dubowitz et al., 2012), HR (Belojevic et al., 2008) and SC (Alvarsson et al., 2010) can be influenced by environments people live in. Hence in this research, the electrophysiological measures when consuming food in laboratory and real environments will be investigated to provide an objective measure of emotions that might help explain why changes in flavour perception over time may occur.

The objective of this study is to analyze the influence of laboratory and real environments on temporal flavour perception, consumer emotion and electrophysiological measurements when consuming chocolate ice cream.

Chapter 3 Materials and Methods

3.1 Experimental procedure

The flow chart shown in Figure 3.1 depicts the experimental design used in the research. Chocolate ice cream was consumed by participants in four different environments as shown in Figure 3.2: (a) sensory laboratory, (b) café, (c) bus stop, and (d) university study area. In each environment, electrophysiology, sensory and emotion measurements were obtained. Firstly, electrophysiological measurements were obtained when 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. Secondly, the Temporal Dominance of Sensations (TDS) method was employed to measure temporal flavour changes of chocolate ice cream over 45 seconds. At the end of TDS assessment, participants rated their affective state in terms of valence, arousal and dominance. Finally, participants selected emotion attributes they experienced in each environment from a list of emotions provided. Participants were provided with a 5-min break to drink some water to avoid fatigue in between electrophysiology, sensory and emotion measurements.

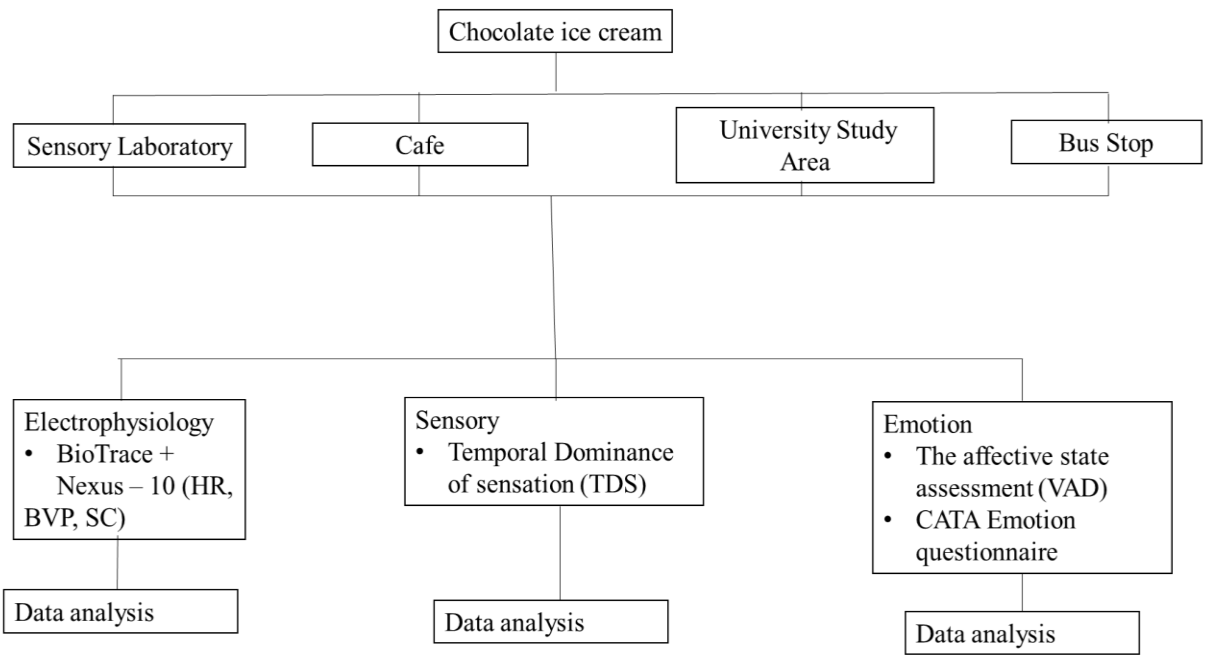

Figure 3.1 Experimental design used in this study

Figure 3.2 The laboratory (a), café (b), bus stop (c) and university study area (d) environments where ice cream was consumed by participants

3.2 Ethics statement

Ethics approval for this study was granted by the Auckland University of Technology Ethics Committee (AUTEC 17/202). Participants were provided with informed consent forms prior to commencement of the study.

3.3 Background Sound Recording

The background sounds of the different environments (lab, café, university study area, bus stop) were recorded weekday between 11:00 – 12:00 p.m. by using a Sennheiser headset (Series HD 518: Sennheiser Electronics GmbH and Co. KG, Wedemark, Germany) connected to a standard PC sound card. The psychoacoustics parameters (tonality, sharpness roughness and fluctuation strength) were used to define the sound of each environment (Fastl & Zwicker, 2007). Tonality was used to measure the relative content of pure tones of a sound signal. Sharpness was used to measure the relative content of high frequencies and roughness was used to measure the modulation with low frequencies (15 – 300 Hz) in a sound signal. Fluctuation strength was used to measure the amplitude modulation of a sound signa. The National Instruments LabVIEW 2013 software (Austin, TX, U.SA) was used to calculate the psychoacoustical parameters.

3.4 Sample preparation and presentation

Chocolate ice cream was used in this study as chocolate an emotional food. Fiegel et al. (2014) reported that the overall impression of emotional food (chocolate) was significantly higher compared to non-emotional food (bell peppers) after listening to different music genres. The chocolate ice cream samples were made up of 60% cream, 16% milk, 15.7% sugar, 8% cocoa powder and 0.3% vanilla extract. The 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 cup (45 mm diameter) and frozen in a commercial-grade freezer (Fisher and Paykel, NZ) at -18 ℃ for at least 24 h prior to serving to ensure sample consistency. All samples were thawed for one minute at room temperature before serving. The serving temperature (-12 ± 2 ℃) was strictly controlled to maintain consistency.

3.5 Participants

One hundred and sixty participants (50 males, 110 females) aged between 20 and 40 years old were recruited in this study. Forty participants carried out experiments in each environment. Participants were recruited by advertisements placed around the university. Participants were excluded if they were smokers, or reported any health problems that may experience. The study was carried out between 11:00 am and 2:00 pm.

3.6 Panel training

Panel training was carried out for about 10 h on the basic knowledge of temporal dominance of sensation (TDS). Participants were told that they would go to either the laboratory, cafe, bus stop or university study area when consuming chocolate ice cream. Firstly, participants were introduced to the concept of dominance and how it was measured. The dominance attributes were described to participants as the attribute associated to the sensation catching participant’s attention at a given time, and they were made to understand that dominance might switch when a new sensation arrives (Labbe, Schlich, Pineau, Gilbert, & Martin, 2009; Pineau et al., 2009). Furthermore, the intensity of a chosen dominant attribute was rated by participants using an unstructured line scale anchored “none” and “extreme” at each end (Pineau et al., 2009). Participants were also familiarized with the measure of flavour sensations of ice cream using TDS by implementation of a dummy TDS trial during training.

3.7 Temporal Dominance of Sensation

Temporal Dominance of Sensation (TDS) was used to analyze the temporal flavour changes in ice cream flavour as described by Pineau, Cordelle, Imbert, Rogeaux, & Schlich (2003). 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 et al., 2016). Each TDS session lasted 45 seconds long under each eating environment. The TDS screenshot of what participants viewed when they carried out the experiment in this study is shown in Figure 3.3. All sensory data acquisition was done using FIZZ Acquisition 2.46b (Biosystemes, France).

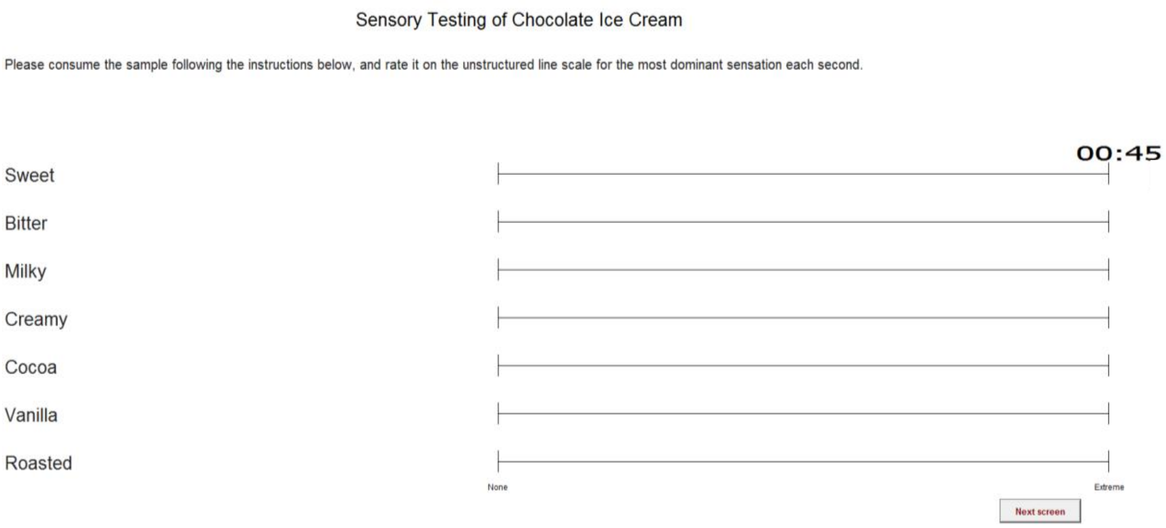

Figure 3.3 The representation of the TDS assessment screen

3.8 Emotional response of environment

The Self-Assessment Manikin (SAM) emotion attributes as described by Bradley & Lang (1994) were used in this study to analyze participants' affective responses after consuming ice cream in the different environments. Table 3.1 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 3.1.

Table 3.1 Description of the Self-Assessment Manikin emotion attributes provided to participants

Affect attributes	Description	Anchors	Reference
Valence	The pleasantness of the stimulus	From 'unpleasant' to 'pleasant'	*Soleymani et al., 2008; Warriner et al., 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 control exerted by the stimulus	From 'control' to 'in control'	*Warriner et al., 2013*

Participants were also required to select emotion attributes after consuming food in the laboratory and real environments. Definitions of emotion attributes provided to participants are shown in Table 3.2 The 20 emotion attributes selected were provided by a focus group of 40 participants who selected emotions that they experienced in different environments (laboratory, café, bus stop, university study area) from a list of emotions provided. A Check-all-that-apply (CATA) emotion questionnaire was provided to participants in this experiment. Emotions in the list were selected from the Profile of Mood States Questionnaire (McNair, Droppleman, & Lorr, 1971), Multiple Affect Adjective Checklist-Revised (Lubin & Zuckerman, 1999), Positive and Negative Affect Schedule (Watson, Clark, & Tellegen, 1988) and Geneva Affect Label Coder (Scherer, 2005).

Table 3.2 Emotions investigated in this study

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

3.9 Electrophysiological measures

Heart rate (HR), blood volume pulse (BVP) and skin conductance (SC) were measured using a Nexus 10 device (24-bit A-D converters per channel with DC coupled amplifiers) and BioTrace + software (version V2011B1. 2004-2010 Mind Media B.V. Roermond, Netherlands). The Nexus-10 device was used to obtain HR, BVP and SC responses. The BioTrace+ software was used to analyze electrophysiology data. Electrodes (gelled Ag/AgCl) were used to measure the participant's cardiac and SC activity. The standard three-lead electrode configuration was used to get the electrocardiogram, and SC response was measured from the 3rd and 4th digits (middle phalanx) of the non-dominant hand. HR and BVP signals were recorded with the Nexus-10-Heart Rate sensor attached the left index finger using 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 asked not to move their non-dominant hand during the experiment. All signals were recorded at a data sampling rate of 32 data samples per second using the BioTrace + software.

3.10 Data Analysis

3.10.1 TDS curve

TDS dominance curves showed the dominance rating of every attribute over time by using in-built spline-based smoothing algorithm in the FIZZ software (Pineau et al., 2009). Temporal dominance curves displayed the percentage of participants who recognized the prescribed attributes as being dominant at a given time (Pineau et al., 2009). TDS time was presented as standardized time, and data was converted to percentages (0% to 100%) (Ares et al., 2015). The significant (P_s) and the chance (P_0) levels were determined from the panel curves. The P_s and P_0 levels were calculated according to the equation below (Pineau et al., 2009):

$$P_0 = {}^{1}/_{p}$$

$$P_s = P_0 + 1.645\sqrt{\frac{P_0\,(1 - P_0)}{n}}$$

Where

P_0 : Chance level

p : Number of attributes

P_s : Significance level

n : Number of TDS observations ($number\ of\ subject \times replication$)

3.10.2 Canonical Variate Analysis

Canonical Variate Analysis (CVA) was used to analyse the differences between standardized (Std) durations (%) of sensory perception of chocolate ice cream samples and the frequencies of emotions perceived under different environments using XLSTAT (version 2018.5) (Addinsoft, U.S.A). CVA minimizes residual variability and maximizes the distances between samples (Delarue & Sieffermann, 2004). CVA in this study was applied on results from frequencies of emotion perception, and TDS standard durations data calculated by the FIZZ software (Biosystemes, France). Furthermore, the Multivariate Analysis of Variance (MANOVA) tests were used to determine if significant differences exist between each environment in terms of std durations of flavour ($\alpha = 0.05$).

3.10.3 TDS oral trajectory plots

The principal component analysis (PCA) is a kind of multivariate analysis method, which can be used to explore multidimensional data with quantitative variables (Pineau et al., 2008). PCA was carried out the dominance rate of every dominant attribute over time after consuming chocolate ice cream by using XLSTAT (version 2018.5) (Addinsoft, U.S.A).

The datasets of PCA was used to make a global representation of the trajectory of each environmental condition in relation to evolution of the dominance in flavour perception based on the first and second principal components. The dominant flavour responses trajectories of each environment are shown in the figure by connecting the time points (from the first beginning score (t_0) to the last score (t_{100}) point). The time points were shown as 0%, 10%, 20%...100% of the TDS standardized time (Saint-Eve et al., 2015), with a total of 11 standardized time points for each environment.

3.10.4 Analysis of emotion responses

The Cochran's Q test was used to analyze the frequencies of emotion responses in different environments using XLSTAT (version 2018.5) (Addinsoft, U.S.A). The data of emotion attributes was binary (0: not selected, 1: selected).

One-way repeated measures ANOVA (RM-ANOVA) was then used to analyze significant differences (α=0.05) in emotional responses elicited under different environments. The Tukey's multiple comparison tests were applied for analyses that reached statistical significance (Addinsoft, U.S.A).

3.10.5 Electrophysiological measurement

Average values of physiological parameters measured (i.e. BVP, SC and HR) were extracted. The five minutes baseline measurement was used as reference. The percentage change from the baseline was calculated according to the equation below (Zhang & Han et al., 2009):

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

One-way repeated measures ANOVA and two-way repeated measures ANOVA were carried out on the percentage change in electrophysiological measurements in the different environments and judge effect as factors that were taken into account. The Tukey *post-hoc* comparisons tests were used when significance was found (Addinsoft, U.S.A).

Chapter 4 Results

4.1 Psychoacoustic characteristics of sounds in different environments

The psychoacoustic characteristics of sounds in the different eating environments are summarized in Table 4.1. Café sound had the highest sharpness, tonality and fluctuation strength values compared to the bus stop, university study area and laboratory environments. In addition, the bus stop sound had the highest roughness followed by café, lab and university study area environments.

Table 4.1 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 (*acum*)	2.27	2.35	1.1	1.59
Roughness (*asper*)	0.14	0.0018	0.00031	0
Fluctuation Strength (*vacil*)	0.65	2.50	0.14	1.66
Tonality (*sone*)	0	0.014	0	0

4.2 Preliminary trial to determine emotion responses of participants in different environments

A pilot test was carried to determine the emotions evoked by 97 participants in four different environments (sensory laboratory, bus stop, café and university study area) in the vicinity of Auckland University of Technology.

In the laboratory environment, 29 participants selected 67 positive and 22 negative emotion attributes. In the café environment, 139 positive and 56 negative emotion attributes were chosen by 23 participants. In the university study area, 22 participants experienced a total of 258 positive and 85 negative emotion attributes. In contrast, the bus stop environment evoked 56 positive emotion attributes and 113 negative emotion attributes by 23 participants making it the environment associated with the most negative emotions.

4.3 Temporal Dominance of Sensations

Figure 4.1 depicts the spline smoothed TDS curves that describes the dominance rate of temporal flavour of chocolate ice cream 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. It can be seen that sweetness was the first dominant attribute in all four environments. The dominant attributes after sweetness however varied with the different environments.

Under the control 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 – 37% ST, with a maximum rate of 28% at 30% ST. Sweetness then became dominant from 50-67% ST. Roasted was dominant from 81 – 87% ST, reaching a maximum dominance of 25% at 84% ST. Finally, cocoa was dominant from 92% ST until the end of the mastication.

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

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

In the bus stop environment, sweetness was dominant at the start and slowly decreased from a maximum dominance rate of 38% between 0 – 10% ST similar to the control laboratory environment. However, bitterness was 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% on 35% ST and 30% on 42, 58 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.

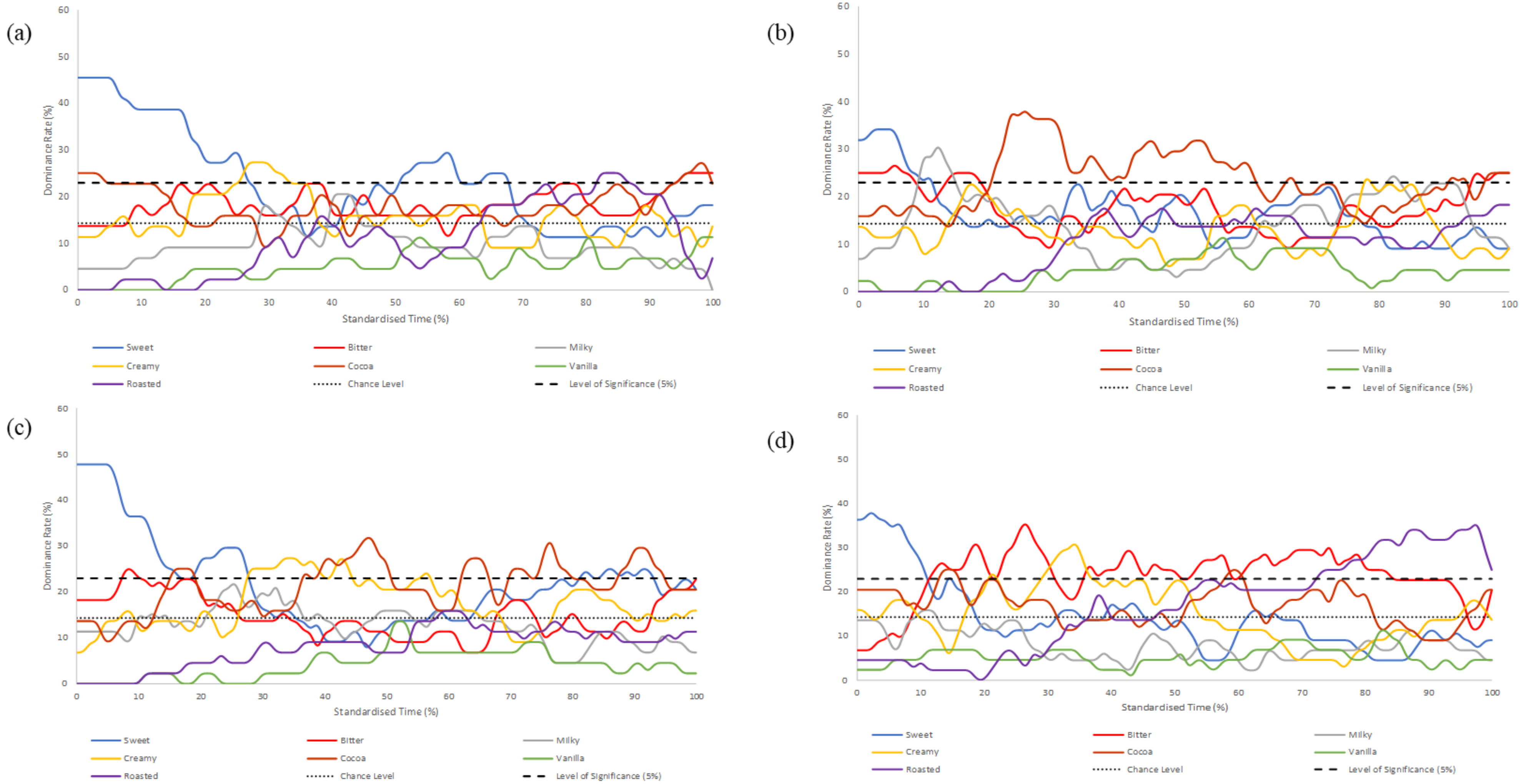

Figure 4.1 Panel dominance rates (%) of the seven sensory attributes presented in the TDS sessions expressed in standardized time (%). TDS curves are for the four environments: sensory laboratory (control) (a), university study area (b), cafe (c), and bus stop (d).

4.4 Flavour trajectories of chocolate ice cream in different environments

PCA was carried out 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 (Figure 4.2). For each of four environments, a trajectory of perceived dominant attributes was shown in the figure.

Sweetness was always the first perceived attribute in the laboratory (20% of the trajectory time), university study area (7% of the trajectory time), bus stop (12% of the trajectory time), and cafe (20% of the trajectory time) environments. In the café environment, milkiness and cocoa were at 32% and 58% of the trajectory time respectively. Creamy and sweet flavours were perceived at the end of mastication, at 94% and 96% of the trajectory time respectively. When ice cream was consumed under the university study area environment, roasted, vanilla and cocoa were perceived after sweetness perception, at 45%, 50% and 69% of the trajectory time respectively. In the laboratory environment, creamy and cocoa flavours were perceived at 45% and 48% of the trajectory time respectively. Cocoa flavour was further perceived at 72% of the trajectory time, and vanillas flavour perceived at 74% of the trajectory time. Finally, roasted flavour was perceived at 86% of the trajectory time. Ice cream consumed under bus stop environment was bitter at 22%, 38% and 45% of the trajectory time. All the results explained is in agreement with the results TDS sensory profile shown in Figure 4.1.

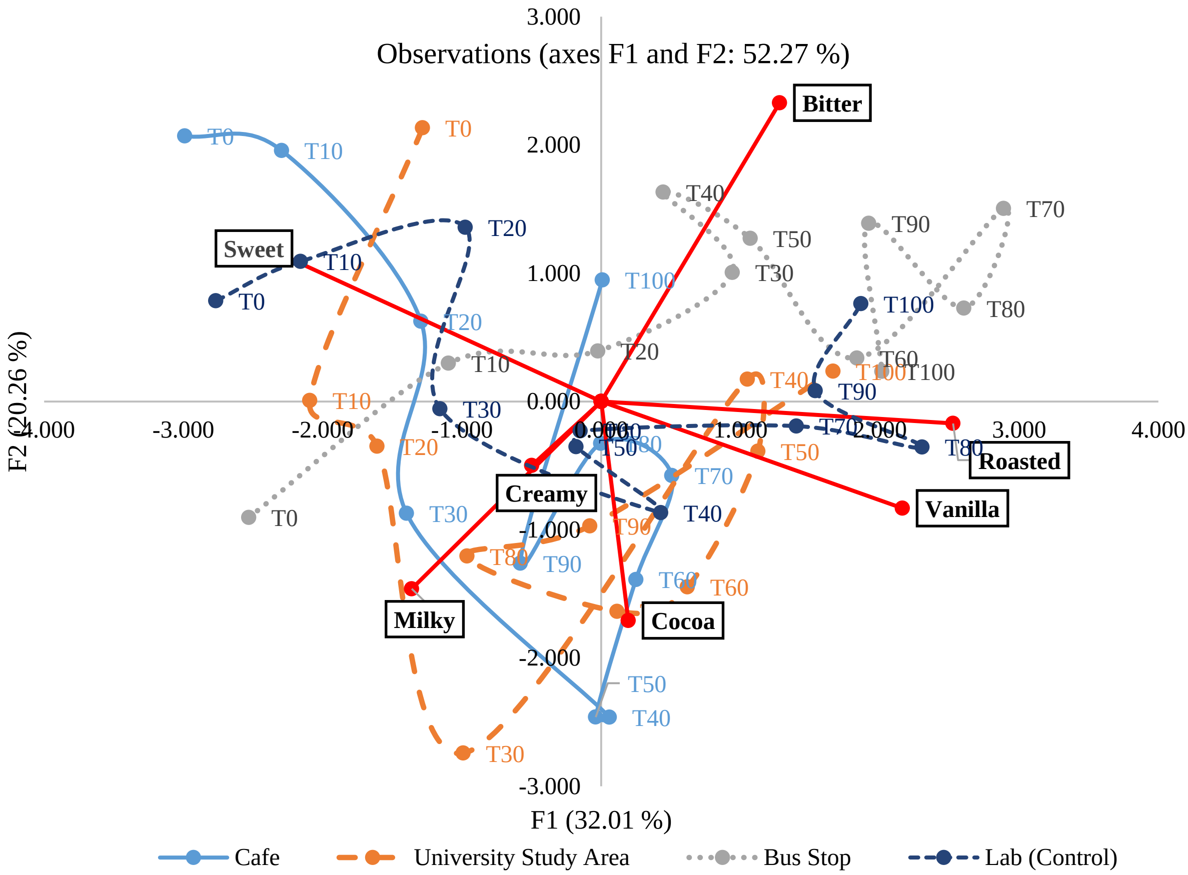

Figure 4.2 Principal component analysis biplot showing the flavour trajectories of chocolate ice cream consumed in the laboratory, café, study area and bus stop environments.

4.5 CVA of chocolate ice cream in different environments

CVA was used to further summarize the standardized duration of flavour when ice cream was consumed in different environments. Figure 4.3 described that the first two canonical variates explained 95.20% of the data. The 90% ellipse represent as multidimensional confidence intervals of means of the standardized duration of flavour when ice cream was consumed in different environments. The separation of ellipses showed that related environments were distinguished, which demonstrated that the standardized duration of flavour differed significantly when ice cream was consumed in the four environments differed significantly (Peltier et al., 2015).

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

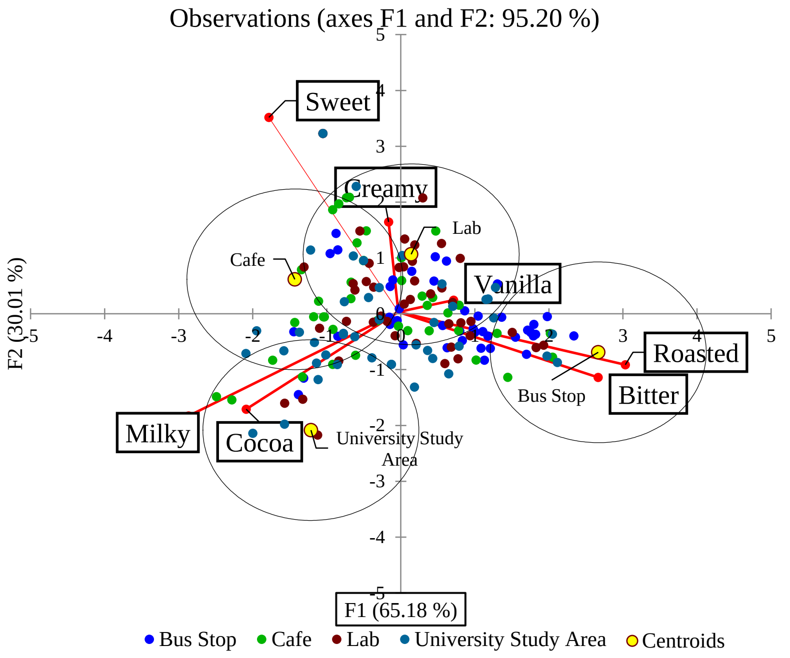

Figure 4.3 Canonical Variate Analysis biplot of dominance durations of sensations. Hotteling-Lawley MANOVA test showed significant product differences (F(7, 168) = 2.682; p < 0.05) based on sensory attributes.

4.6 Affective dimensions

Panellists rated the affective dimensions of four different environments here ice cream was consumed. Figure 4.4 showed that the four eating environments to be significantly different in terms of valence, arousal and dominance.

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

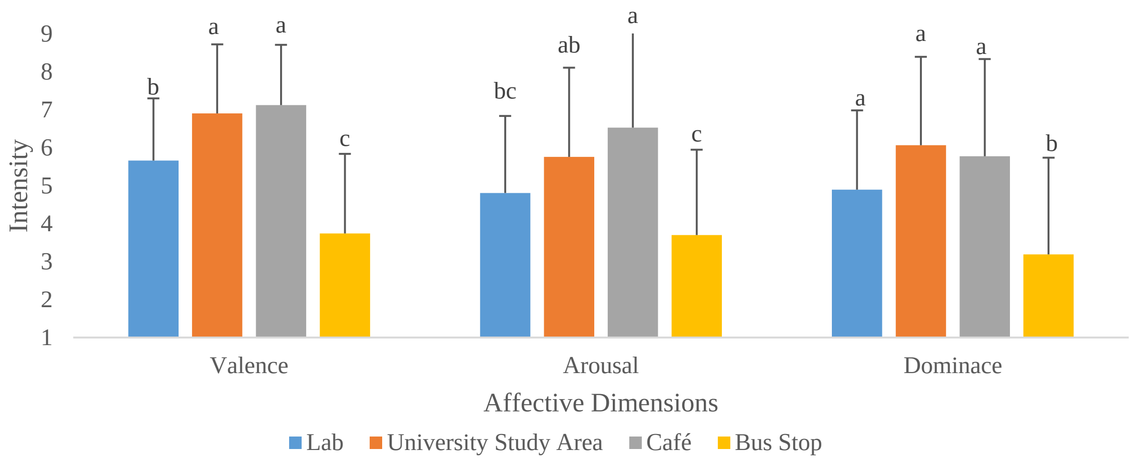

Figure 4.4 Affective ratings of valence, arousal, and dominance in different environments (laboratory, university study area, café and bus stop) after consuming chocolate ice cream [a,b,c] indicate: mean affective ratings of environments with different letters indicating significant differences affective dimensions.

4.7 Relationship between emotion responses and the different eating environments

All these emotion attributes in Table 4.2 were based on a pilot trial to determine emotions perceived by participants in the different environments. The frequencies of the emotion responses evoked by a total of 97 participants showed significant differences between the four environments. It was found that the university study area environment had the highest number of positive emotion attributes followed by café, laboratory and bus stop environments. The bus stop environment on the other hand had the highest number of negative emotion attributes followed by university study area, café and laboratory environments.

Negative emotions of unable to concentrate, uncertain about things, negative, tired, tense, unhappy, annoyed and anxious (Table 4.2) were rated significantly higher in the bus stop environments compared to the laboratory, university study area and café environments after consuming chocolate ice cream.

Table 4.2 Self-rated emotions following the consumption of chocolate ice cream under different environments (laboratory, university study area, café and bus stop). * represents significance using one-way ANOVA observed for the emotion terms across the four environment conditions. 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*

4.8 CVA of emotions experienced after consumption in the different environments

CVA was applied in order to further explain the relationship between emotion attributes and the different environments, and the results are summarized in Figure 4.5. The first two canonical variates explained 94.05% of the data. The 90% confidence ellipses demonstrated that the emotions experienced by participants in the four eating environments differed significantly due to the separation of ellipses (Peltier et al., 2015). The Hotelling-Lawley MANOVA analysis results ($F_{(63,343)} = 10.682$, $P < 0.001$) showed significant differences between emotional responses when ice cream was consumed in different environments. The bus stop environment was correlated to negative emotions of tense, tired, negative, anxious, annoyed, unhappy, and unable to concentrate uncertain about things. The university study area environment was corelated to negative emotions of lost and composed, and positive emotions of calm, excited, and at ease. The café environment was correlated to positive emotions of joy, happy, pleasure, cheerful, positive and satisfied. The lab environment was correlated to the positive emotion of concentrating.

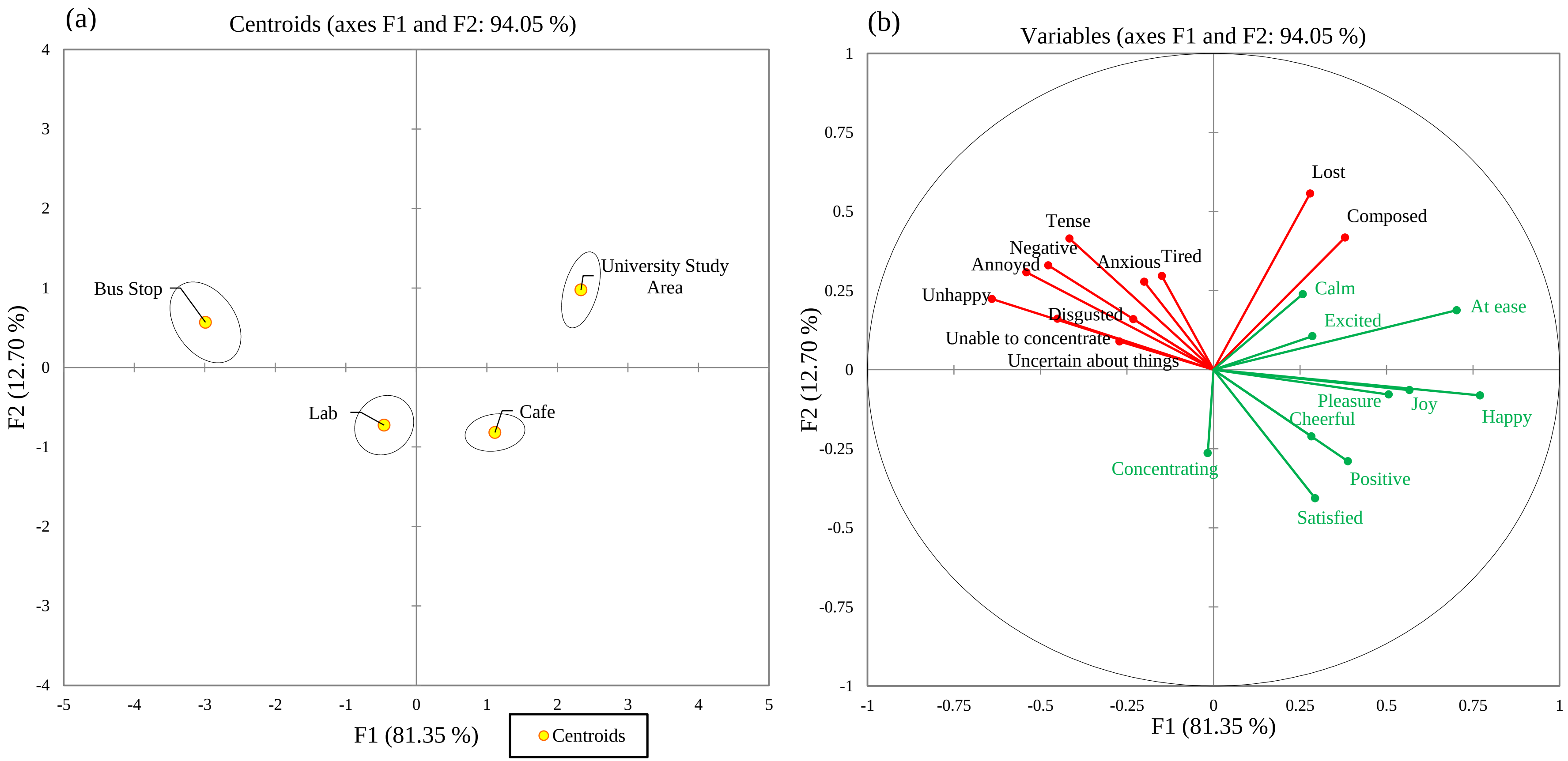

Figure 4.5 Canonical Variate Analysis Biplot of dominance durations of sensations. Hotelling-Lawley MANOVA test showed significant product differences ($F(63,343) = 10.682$, $p < 0.001$) based on emotion attributes. (a) showing the variables of each environment which are correlated with the two factors on the factor axes (b) showing the 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.

4.9 Relationship between sensory perception and emotional responses in the different eating environments

The CVA plot in Figure 4.6 depicts the relationship between the standardized duration of sensory perceptions and the frequencies of emotional responses, when ice cream was consumed in different environments. The first two canonical variates explained 93.83% of the data. The 90% confidence ellipses demonstrated that the frequencies of emotions and flavour perception of ice cream differed significantly in the four eating environments (Peltier et al., 2015). The Hotelling-Lawley MANOVA analysis results ($F_{(84,336)}$= 8.433, $p < 0.001$) showed significant differences between sensory perception and emotional responses when ice cream was consumed in 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 in the bus stop environment. 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.

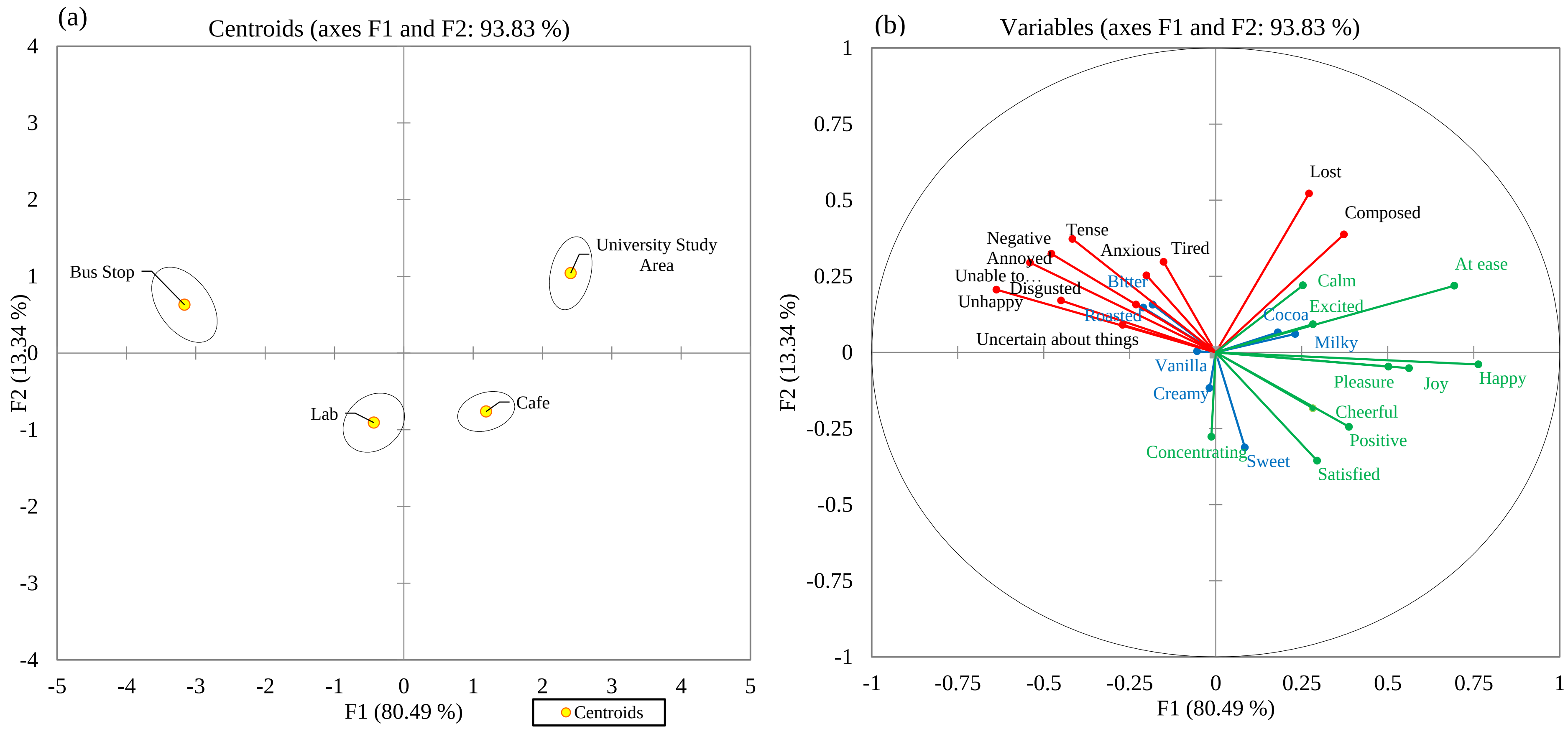

Figure 4.6 Canonical Variate Analysis Biplot of dominance durations of sensations. Hotelling-Lawley MANOVA test showed significant product differences ($F_{(84,336)}$= 8.433, p < 0.001) based on sensory attributes and emotion responses. (a) showing the variables of each environment which are correlated with the two factors on the factor axes (b) showing the 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.

4.10 The effect of eating environments on electrophysiological responses

The influence of eating ice cream in the different eating environments was significantly different using one-way RM-ANOVA for SC ($F_{(3,156)} = 3.149$, $p < 0.05$), HR ($F_{(3,156)} = 2.673$, $p < 0.05$) responses as illustrated in Figure 4.7. SC was significantly higher when eating ice cream in the university study area environment compared to the lab environment. HR was significantly lower in the university study area environment compared to the bus stop environment after consuming ice cream. In contrast, no significant difference was found for the BVP amplitude ($F_{(3,156)} = 0.202$, $p > 0.05$) response between the different environments.

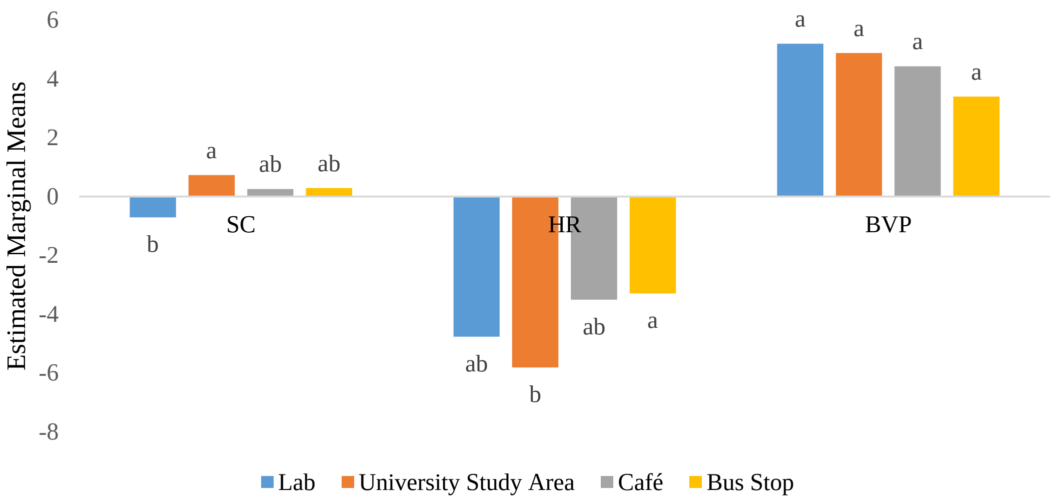

Figure 4.7 Skin conductance (SC), blood volume pulse (BVP), and heart rate (HR). values calculated based on changes in baseline without eating ice cream compared to one-minute of eating ice cream in laboratory, café, university study area and bus stop environments. Different [a,b,c,d] superscripts indicate significant difference in physiological values using the Tukey's multiple comparison tests.

4.11 The influence of gender on electrophysiological responses in different eating environment

Two-way RM-ANOVA was significant for the effect of gender and environments on HR ($F_{(7,152)} = 3.153$, $p < 0.01$). Figure 4.8 showed that the HR of female assessors was significant decreased in the university study area environment compared to the bus stop environment after eating ice cream. However, the HR of male assessors had no significant difference between the lab, café, university study area and bus stop environments.

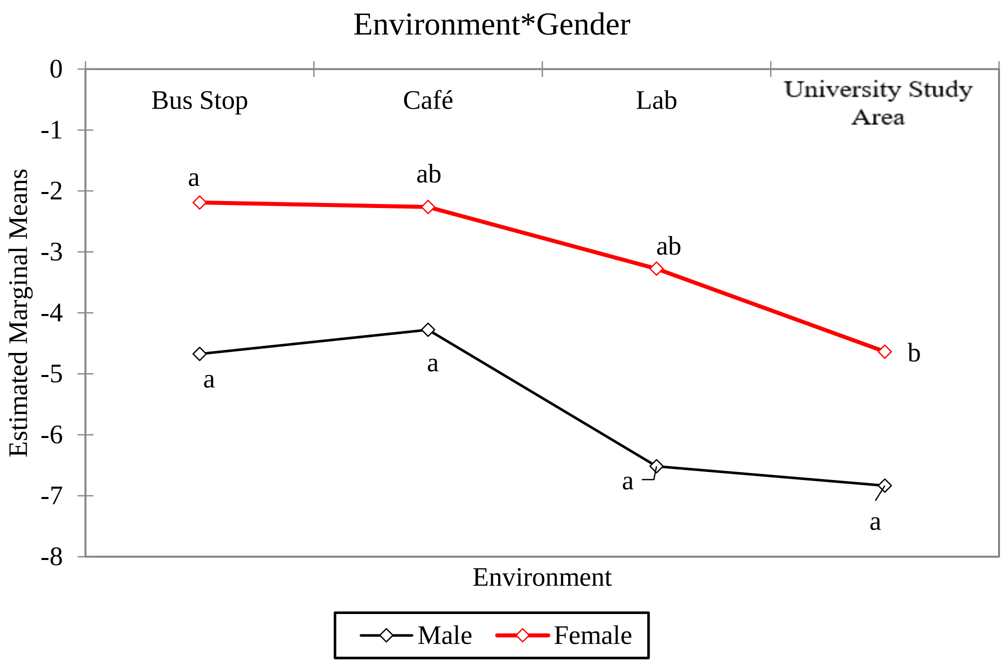

Figure 4.8 Physiological measure of heart rate (HR). Values were calculated based on the changes in baseline (without eating ice cream) compared to one-minute of eating ice cream in terms of gender and environment conditions. Different [a,b,c,d] superscripts indicate significant differences in physiological values using the Tukey's multiple comparison tests.

Chapter 5 Discussion

5.1 Psychoacoustic characteristics of sounds varied in different environments

In this study, café sound had the highest fluctuation followed by university study area, bus stop and lab conditions. Similarly, Kantono et al. (2016b) reported that café sound had the highest fluctuation value, which may result in a relative quite condition by masking the low amplitude sounds which may come from the air conditioner or refrigerator. On contrary, the bus stop sound had the highest roughness followed by café, lab and university study area environments, and the lowest fluctuation value compared to café and university study area environments. Özcan & van Egmond et al. (2012) reported that participants listening to mechanical sound with higher roughness found it 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. Participants who perceived sounds as louder, sharper or rougher may perceive less pleasantness as reported by the Zwicker's the model of psychoacoustics and sensory pleasantness (Fastl & Zwicker, 2007). Hence, findings in this study may suggest that the café sound was considered the most pleasant, and the sound of the bus stop environment was the most unpleasant.

5.2 Emotion responses varied in different environments

Based on results from the preliminary trial, it can be seen that participants in the four different environments experienced varying emotion responses. In this study, the university study area environment elicited the high number of positive emotions followed by the café environment. Many studies have shown that the restaurant environment was related to positive emotions (Hyun et al., 2014; Jang & Ryu, 2007, Prayag et al., 2014). On contrary, in this study, the bus stop environment elicited a high number of negative emotions. Ulrich et al. (1991) also reported that the traffic environment elicited a higher negative emotion of anger compared to the pedestrian mall environment. Paunović et al. (2014) further reported that the public transport noise (more than 70dBA) at day time elicited a higher negative emotion of annoyed compared to the noise without public transport noise (more than 70dBA).

5.3 Dominance of ice cream flavour perception varied in different eating environment

In the laboratory environment, chocolate ice cream was perceived the most dominant in terms of sweetness and then creaminess at the beginning of mastication, but turned to be roasted and cocoa at the end of the mastication period. Kantono et al. (2018) also reported that the bittersweet chocolate gelato was perceived as being dominantly sweet and creamy thereafter in the early mastication period under the silent laboratory environment.

Cocoa flavour was in fact dominant in both café and university study area environments but with a higher dominance rate in the latter environment from the early beginning until the end of mastication period. Kantono et al. (2018) also reported that bittersweet chocolate gelato was perceived as being dominantly cocoa in the early mastication period when listening to the neutral and liked music. In addition, Kantono et al. (2016b) showed that the intensity of pleasantness was increased when listening to the café sound after consuming chocolate gelato.

In the bus stop environment, sweetness was domiant at the beginning mastication period but at a lower dominance rate than control and café environments. This was followed by a long dominance of bitter taste interrupted by a dominance of creaminess that differentiated this environment from the other three environments. Similarly, bitter flavour was dominant from 60% ST until the end of mastication in bittersweet (Kantono et al., 2018) and milk (Kantono et al., 2016a) chocolate gelato when listening to disliked music in both studies. Kantono et al. (2016b) also showed that the intensity of pleasantness was decreased when listening to the bar sound after consuming chocolate gelato. Interestingly, Kantono et al. (2018) also found that creaminess was dominant at the start of mastication when consuming bittersweet chocolate gelato while listening to disliked music.They postulated that this may be due to the fact that creamy flavour acted as a mild stressor. Torres and Nowson (2007) found that participants might desire high-fat content food like ice cream (Guinard et al., 1997) when they were under stressful conditions, which might also explain why creamy was dominant in the bus stop environment. TDS analysis of chocolate containing 85% cocoa (Jager et al., 2014) and chocolate bars containing 55% and 70% cocoa (Rodrigues et al., 2016a) were perceived to result in a long dominance of bitter flavour until the end of mastication stage.

5.4 CVA of ice cream perception in different environments

The CVA results in this study showed that chocolate ice cream consumed in the four different environments were associated with different flavours.

Different environments have been reported to affect flavour intensity of food attributes. Pound et al. (2000) reported that the intensity of sweetness and chocolate flavour of chocolate bars significantly increased in the central location and home environments compared to the sensory laboratory. The home environment was reported to be more uncontrolled compared to laboratory environment (Pound et al., 2000).

Other studies showed that liking of food was affected by the environment the food was consumed in. Sosa et al. (2008) further showed that the appearance and flavour of the chocolate milk were significantly liked at home compared to the institute room. Zhang (2017) found that the liking scores of sweetness, milky flavour and vanilla flavour of protein beverages with acesulfame potassium and sucralose addition were significantly higher at home compared to central location.

Ice cream consumed in the café environment was related to sweet in this study. Petit et al. (2007) also reported that the frequencies of sweet taste of milk-based iced coffee was higher in the cafeteria environment compared to the laboratory. Consumption of ice cream in the university study area environment was associated with milky and cocoa flavour. Petit et al. (2007) also reported that the frequencies of milk taste of milk-based iced coffee was higher in the meeting room compared to the laboratory.

Consumption of chocolate ice cream in the bus stop environment was associated with roasted and bitter flavours. Kantono et al. (2016a) also reported that consumption of bittersweet chocolat gelato was associated with bitter flavour when listening to disliked music.

5.5 Affective dimensions varied in different eating environments

The Mehrabian-Russell model (M-R model) (1974) described how participants' emotional responses (i.e. arousal, dominance, pleasure) can be influenced by the environmental factors such as colour, odour, textures, sounds and temperature (Mehrabian & Russel, 1974). In the M-R model, pleasure was described as the degree of participants' feeling in a situation (i.e. happy, joyful, or good). Arousal was explained as the degree of excitability of participants, and dominance was the degree of controlled feeling of participants in one place (Mehrabian & Russell, 1974). The affective states (i.e. valence, arousal, dominance) of this study based on the M-R model were used to explain the participants' emotion responses in the different eating environments (lab, café, university study area and bus stop) after consuming chocolate ice cream.

In this study, the valence rating was significantly increased in the café and university study area environments after consuming chocolate ice cream compared to the control and bus stop environments. In this study, the psychoacoustic characteristics of sound in the cafe environment was considered the most valent in terms of the highest fluctuation, and the bus stop environment was the least valent in terms of lowest fluctuation and highest roughness. Similarly, Kantono et al. (2016c) demonstrated that valence rating was significantly higher in the café condition (under both sound and audio-visual conditions) after consuming the dark, bittersweet and milk chocolate gelato compared to the control silent environment.

In this study, the arousal rating was significantly higher in the café and university study area environments after consuming ice cream compared to bus stop and laboratory environments. High arousal and valence ratings were related to appetitive (i.e. approach) behaviours, while with high arousal and low valence rating were related to defensive (i.e. avoidance) behaviours (Bradley & Lang, 2000; Bradley et al., 2001). In our study, it can be concluded that the café and university study area environments that had the higher arousal and valence dimensions would evoke the most appetitive behaviour. The bus stop environment (i.e. low arousal, low valence, low dominance) in turn was associated with non-appetitive or non-defensive behaviours.

In this study, the dominance rating was significantly increased in the university study area and café environments after consuming ice cream compared to the bus stop environment. Kantono et al. (2016b) also showed that the dominance ratings was significantly increased in the café sound condition (with and without visual) after consuming the dark, bittersweet and milk chocolate flavours of gelato compared to the control silent condition.

5.6 Relationship between emotion responses and the different eating environments

The cognitive theory of emotion demonstrated that the subjective evaluation of participant emotion can be affected by environment factors (Lazarus, 1991). In addition, Piqueras-Fiszman & Jaeger (2014) demonstrated that the suitability and context of eating environment had a significant effect on a multitude of participants' perceptions (i.e. perceived emotions).

In this study, positive emotions of pleasure, happy, positive and satisfied were rated significantly higher in the café and university study area environments compared to the laboratory and bus stop environments after consuming chocolate ice cream. Many studies have also reported that good atmosphere of restaurants was related to positive emotion responses, which support our results for our café environment. Prayag et al. (2014) showed that the restaurant atmospherics of the restaurants in the French Riviera had a significantly positive effect on the positive emotions of consumers in terms of relaxation, pleasure and excitement. Jang and Ryu (2007) further reported that the high quality ambience of upscale restaurants had significant effects on the emotions of happy, pleased, entertained, delighted of participants. Jang and Namkung (2009) reported that the atmospherics of the full-service restaurant had a significant effect on positive emotions of joy, excitement, peacefulness and refreshment of participants. Jang et al. (2011) also reported that the authentic atmospherics of a mid-scale level Chinese restaurant had a significant effect on positive emotions of pleasure, excitement, contentment, refreshment, interest and relaxation of participants. Similarly, Danner et al. (2016) reported that positive emotions of energetic, happy and loving were rated significantly higher under the restaurant environment after consuming wine compared to home and laboratory environments. Dorado et al. (2016) further showed that the positive emotion of exciting was significantly higher in the pub with freely-elicited scenario (i.e. talking with friends) compared to without freely-elicited scenario when consuming beer.

On the other hand, negative emotions of unable to concentrate, uncertain about things, negative, tired, tense, unhappy, annoyed and anxious were rated significantly higher in the bus stop environment compared to the lab, university study area and café environments after consuming chocolate ice cream. Ulrich et al. (1991) reported that the negative emotions of anger and aggression were significantly increased in the traffic environment compared the pedestrian mall environment. Paunović et al. (2014) further reported that public transport noise (more than 70dBA) at day time elicited the negative emotion of annoyed more compared to without public transport noise (more than 70dBA).

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 valent and were related to positive emotions. Negative emotions on the other hand are more related to the least valent environment, which in this case is the bus stop. In addition, the laboratory environment was found to be the environment that evoked the least emotions.

5.7 CVA of emotions experienced in different eating environments

Chocolate ice cream is an emotional stimulus. Macht & Dettmer (2006) reported that the chocolate bar can influence participants' emotion of joy, due to the sensory pleasure after consuming chocolate. Desmet & Schifferstein (2008) also reported that consuming sweet snacks significantly increased the positive emotions of satisfaction, love and hope compared to consuming savoury snacks. Konttinen et al. (2010) further reported that that sweet and high-fat foods can influence participants' emotion feelings. In addition, Thomson et al. (2010) showed that dark chocolate was related to positive emotions of energetic and confident.

Environment factors can influence participants' emotion feelings. Barrett et al. (2007) demonstrated that participants' emotions were not just influenced by the stimulus itself, but also influenced by the social and situational environments. In this study, the cafe environment and university study area environments were the most valent environments according to the affective dimension results, and were correlated to more positive emotions after consuming chocolate ice cream. Kim and Moon (2009) found that the ambient condition, facility aesthetics, layout, electric equipment, and seating comfort of theme restaurants in Alberta and Canada had significant effects on the pleasure effect of happy, pleased, entertained and delighted of participants. Jang and Ryu (2007) further reported that the facility aesthetic, and the high quality ambience of upscale restaurants had significant effects on the pleasure of happy, pleased, entertained and delighted of participants in the U.S. The ambience of upscale restaurants had a significant effect on arousal.

On the other hand, the bus stop environment that was found to be the least valent environment according to the affective dimension results was corelated to more negative emotions. Urban & Máca (2013) showed that listening the road and railway noises evoked annoyance of participants due to noise that had a negative effect on participants' satisfaction.

5.8 Relationship between sensory perception and emotional responses in the different eating environments

Emotional feelings can affect sensory perceptions (Jaeger et al., 2018; Prescott, 2017; Danner et al., 2016; Köster et al., 2015). In this study, the negative emotions of tense, tired, anxious, negative, annoyed, unable to concentrate, unhappy and uncertain about thingswere associated with bitter and roasted flavours in the bus stop environment.

Similarly, some studies have shown that negative emotions are associated with bitter taste. Kantono et al. (2016a) demonstrated that negative emotions of disgust, contempt and disappointment were related to bitter taste when consuming bittersweet chocolate gelato under disliked music condition. Likewise, Jager et al. (2014) showed that negative emotions of bored and aggressive were related to bitter taste when consuming chocolate containing 70% cocoa.

In this study, the positive emotions of happy, pleasure, joy, cheerful, positive and satisfied were associated with sweet taste in the café environment. Studies have also reported that positive emotions were associated with sweet taste Kantono et al. (2016a) correlated positive emotions of happiness, satisfaction to sweet taste when listening to liked music after consuming chocolate gelato. Likewise, Jager et al. (2014) showed that positive emotions of interested, happy, loving were related to the sweet taste of orange and blueberry flavour chocolate. Thomson et al. (2010) also reported that positive emotions of fun, easy-going were related to the sweet flavour of chocolate. Interestingly, it was also found that positive emotions of at ease and excited were related to milky flavour in the university study area environment. Similarly, Kantono et al. (2018) showed that positive emotions of amusement, enjoyment, love, happiness, satisfaction were related to milky taste when listening to neutral and liked music after consuming gelato.

Results from this study showed that the positive emotions of calm, at ease and excited were associated with cocoa flavour in the university study area environment. Thomson et al. (2010) reported that positive emotions of energetic, powerful were related to cocoa flavour when consuming dark chocolate.

The emotion of concentrating was related to creamy flavour in the laboratory environment. This may because the laboratory is a controlled environment (Kozlowska et al., 2003), and participants were much more likely to concentrate in this environment compared to the other environment.

Based on the results reported, it was found that valence dimensions of the eating environment can affect both emotions and sensory perception. Valent environments (café, university study area) resulted in positive emotions that are related to sweet, cocoa and milky flavours. The least valent environment (bus stop) resulted in negative emotions related to bitter and roasted flavours. The environment that evoked the least emotion was the laboratory that was related to creamy flavour.

5.9 The effect of eating environments on electrophysiological responses

After consuming chocolate ice cream, SC was significantly the highest in the university study area, café and bus stop environments compared to the laboratory. Parsons et al. (1998) reported that the SC of participants significantly increased in the urban roadside environment compared to the forest roadside environment. Alvarsson et al. (2010) further reported that the SC of participants significantly increased in high noise condition compared to the nature sound condition. The reason why the SC was increased may be due to the increase of mental stress when listening to noise (Sun et al., 2010).

After consuming chocolate ice cream, HR was significantly decreased in the university study area compared to the bus stop environment. Zhai & Barreto (2006) reported that HR increased when people were under stressful environments. Studies also have shown that HR can be significantly influenced by the different environmental conditions. Kuo et al. (1999) reported that HR variability can be divided into Very-Low- Frequency (VLF), Low-Frequency (LF) and High-Frequency (HF) ranges on the basis of its frequency. The vagal control of HR was represented by HF. Yanagihashi et al. (1997) reported the HF value was the lowest when listening the unpleasant mechanical sounds compared to the pleasant music synthesizer and bird twitters sounds. The reason is because the parasympathetic nervous system was inhibited, and unpleasant emotion system was amplified when listening mechanical sounds (Hayano et al., 1990). Likewise, Laumann et al. (2003) reported that the HR of participants significantly decreased when watching the natural environment compared to the urban environment on video. Labbé et al. (2007) showed that the HR of participants were significantly decreased under the self-selecting relaxing and classic music conditions compared to the heavy metal music conditions after being stressed.

5.10 The influence of gender on electrophysiological responses in different environment

In this study, the HR of female participants significantly increased in the bus stop environment compared to the university study area environment after consuming chocolate ice cream, while the HR of male participants had no significant difference between the lab, café, university study area and bus stop environments. Kuo et al. (1999) reported that HR variability can be influenced by gender effect. Huikuri et al. (1996) reported that the HR and HF of women significantly increased compared to men when sitting, while the LF of women significantly decreased compared to man when sitting. Kuo et al. (1999) also reported that the HF of women significantly increased compared to men. Dishman et al. (2000) further reported that the LF of women significantly decreased compared to men.

Chapter 6 Conclusion

This study set out to determine how emotions and electrophysiological measures influenced temporal changes in flavour perception of chocolate ice cream in the different environments. The uniqueness of this study exists in the fact that the dominant flavour attributes of ice cream in different environments could be explained in terms of affective dimensions, emotions and electrophysiological measures. Consumption of ice cream in the different eating environments also resulted in temporal flavour changes. The café environment was associated with sweet, the bus stop environment with bitter and roasted, the university study area with cocoa and milky, and the laboratory with creamy. The different environments were also found to evoke different emotions after consuming ice cream. The café that had high arousal and valence ratings were associated with the most positive emotions followed by the university study area. The bus stop was the least valent environment after consuming chocolate ice cream and was correlated to the most negative emotions. The laboratory was the least emotional environment after consuming chocolate ice cream. The different eating environments also resulted in changes in SC and HR. SC was significantly increased in the university study area compared to the laboratory, and HR was significantly decreased in the university study area compared to the bus stop. The results of this research support the idea that emotions and electrophysiological measures influenced temporal changes in flavour perception of chocolate ice cream 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 sensory perception.

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 current study goes some way towards enhancing our understanding on how environments in which food is consumed affect sensory perception. This information can be used to develop targeted interventions aimed at improving perception of food in real-world eating environments.

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Appendix 1

Ethics Approval: 17/202 **How does sound change the flavour of ice cream**

Standard Conditions of Approval

1. A progress report is due annually on the anniversary of the approval date, using form EA2, which is available online through http://www.aut.ac.nz/researchethics.
2. A final report is due at the expiration of the approval period, or, upon completion of project, using form EA3, which is available online through http://www.aut.ac.nz/researchethics.
3. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form: http://www.aut.ac.nz/researchethics.
4. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
5. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.

Non-Standard Conditions of Approval

1. Rewording of the following sentence in the Information Sheet, 'It is not anticipated that you will not experience discomfort or risk…'.