Kevin Kantono

Effects of auditory cues on consumers' affective states, psychophysiological responses, and sensory perception of food.

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School of Science, Faculty of Health and Environmental Science

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Chapter 1. Abstract

The influence of auditory cues such as music or sounds has been largely remained unexplored in the area of food and sensory perception. This thesis investigates the influence of music and environmental sounds on temporal pleasantness and flavour perception. The influence of emotions on crossmodal interactions between auditory cues and food was further explored using subjective (e.g., valence, arousal, and dominance, and measures of specific emotional response), and objective (autonomic nervous system response, ANS) measures.

Experiment One demonstrated that different environmental sounds influenced valence, arousal, and dominance ratings, which directly modulated the pleasantness of chocolate gelati. Chocolate gelati was rated as being highly valent (i.e., pleasant), and low in arousal and dominance when a café soundtrack was played. Listening to a café soundtrack also increased the pleasantness ratings of chocolate gelati. In Experiment Two, the effect of music varying in liking on temporal taste perception was explored using temporal dominance of sensations. Liked music was found to evoke positive emotions (e.g. satisfaction, happiness, and amusement), which was correlated with increased sweetness dominance and lowered bitterness dominance. On the contrary, listening to disliked music evoked negative emotions (e.g. contempt, disappointment, and disgust), which was correlated with increased bitterness dominance, and lowered sweetness dominance. Results also provided evidence that emotions evoked by music influenced taste perception. Experiment Three expanded Experiment Two by investigating the influence of music on gelati flavour in three different environments (laboratory, immersive, and commercial) using the 'temporal check all that apply' approach. In the laboratory environment, listening to liked music showed a higher citation rate of sweetness and milkiness, and listening to disliked music showed higher citation rates of bitterness and creaminess. Interestingly, modulation of taste perception (sweetness and bitterness) by music differed across the commercial venue and the laboratory environment. The immersive environment showed similar changes in temporal sensory perception to those obtained in the commercial environment. The effects of different environments on temporal flavour perception provided ecological validity to the research carried out in this thesis. Finally, Experiment Four demonstrated the changes in autonomic responses (i.e. cardiovascular, respiratory, and electrodermal response), subjective ratings of emotions, and temporal flavour perception, while listening to music varying in valence. A Partial Least Square Regression model showed that sweetness and creaminess were correlated with increased skin conductance and blood volume pulse amplitude, and decreased heart rate. On the other hand, bitterness, milkiness, and cocoaness were correlated with decreases in skin conductance and blood volume pulse amplitude, and increased heart rate. Further Partial Least Square Regression Path Modelling analysis confirmed that increased skin

conductance and blood volume pulse amplitude were positively associated with negative emotions (i.e. anger, contempt, disappointment, and disgust), and negatively associated with positive emotions (i.e. amusement, enjoyment, love, happiness, and satisfaction). In contrast, heart rate was positively associated with positive emotions, and negatively correlated with negative emotions.

This research provided quality empirical data in the impoverished field of crossmodal sensory science. Music influenced affective state, emotions, and autonomic nervous system responses that in turn influenced temporal flavour perception. Further research arising from study's findings include confirming the influence of VAD on food pleasantness using more diverse food samples. In addition, individual differences should also be measured in order to explain and predict the within-panel inconsistencies manifest in sensory and emotional ratings of food. Future research could employ brain imaging technology to identify areas in the brain activated by sounds and how these areas relate to those invested in the sensory perception of food. This will provide further elucidation of the underlying mechanism governing the relationships between sound, taste, and flavour perception.

Chapter 2. Documentations

Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it 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.

<u>Kevin Kantono</u>

Date: 06/03/17

Co-Authored Works & Authors Contributions

Chapter 1 : Listening to music can influence hedonic and sensory perceptions of gelati

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Authors List : Kevin Kantono (80%), Nazimah Hamid (9.5%), Daniel Shepherd (9%), Michelle JY Yoo (0.5%), Gianpaolo Grazioli (0.5%), B Thomas Carr (0.5%)

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Authors List : Kevin Kantono (80%), Nazimah Hamid (9%), Daniel Shepherd (9%), Yi Hsuan T Lin (1%), Charlotte Brard (0.5%), Gianpaolo Grazioli (0.25%), B Thomas Carr (0.25%)

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Authors List : Kevin Kantono (80%), Nazimah Hamid (9%), Daniel Shepherd (9%), Yi Hsuan Tiffany Lin (1%), Selma Skiredj (0.5%), B. Thomas Carr (0.5%)

Kevin Kantono	Nazimah Hamid	Daniel Shepherd	Michelle Yoo	Gianpaolo Grazioli
Thomas Carr	Tiffany Lin	Svetlana Yakuncheva	Charlotte Brard	Selma Skiredj

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Chapter 3. Literature Review

Audition and food perception

The influence that sounds have on food perception has often been underestimated, if not neglected. This review will present studies that explored the effect of auditory and environmental context on consumer behaviour, and sensory perception. Auditory cues discussed include white noise (Woods et al., 2011), musical tones (Crisinel, 2010; Crisinel & Spence, 2009, 2010b, 2011), soundscapes (Carvalho, Wang, van Ee, Persoone, & Spence, 2016; Carvalho, Wang, Van Ee, & Spence, 2016; Crisinel & Spence, 2010a), and music (Fiegel, Meullenet, Harrington, Humble, & Seo, 2014; North, 2012). In addition, this review will also explore the temporal methodologies used in sensory science, and how results obtained will be analysed using a variety of multivariate approaches.

Influence of music and sounds on food perception

White noise and auditory food cues

Studies on white noise sounds that influence sensory perception are summarized in Table 1. Woods et al. (2011) revealed that in loud noise condition (75-85dB) savoury food samples were perceived less saltier while sweet food samples less sweeter compared to a quiet setting (45-55dB). Sounds originating from can also influence sensory perception of freshness and perceived flavour. In a similar study done by Zampini and Spence (2004), potato chips were judged fresher while listening to increased frequency (amplified) compared to decreased frequency (attenuated) of potato chips biting sound. Pellegrino et al. (2015) further showed that white noise (44,100 kHz at 70dB) impaired the ability to discriminate the overall differences between potato chips (Lay's® Original, and a reduced sodium alternative) and carbonated soda samples (Sprite, and Sprite Zero) using the triangle test.

A review paper by Spence, Michel, and Smith (2014) postulated that the suppression of sweet taste under loud conditions may enhance umami taste, explaining why tomato juice or Bloody Mary cocktail which is rich in umami flavour is extremely popular in commercial airlines. Yan and Dando (2015) further confirmed this hypothesis and reported the impact of simulated airline cabin noise on taste perception. Low (27 mM/L), medium (81 mM/L), and high (243 mM/L) concentrations of sucrose were suppressed under loud conditions (80-85 dB airplane noise) compared to silent conditions. In contrast, all umami tastants (3, 9, and 27 mM/L of MSG) were rated as being more intense under loud conditions.

Table 1. Effects of white noise on sensory perception of food.

Sound Stimuli	Food Stimulus	Measured Parameters	Research Outcome	References
Loud background noise (75-85dB) and a quiet setting (45-55dB)	Savoury food samples (Pringles Original Salted Crisps and Cathedral City Mild Mini cheese), and sweet food samples (Sainsbury's Nice Biscuits and Sainsbury's 'all butter' mini Flapjack)	Intensity of sweetness, and saltiness, crunchiness, and liking of food	Samples were perceived less salty and less sweet in loud noise. Samples were perceived crunchier in loud condition. Samples were less liked in loud condition	Woods et al., 2011
Silent condition and airplane cabin noise (80-85 dB)	Tastant solutions (i.e. sucrose, NaCl, MSG) with varying concentrations*	Intensity of sweetness, saltiness, sourness, bitterness, and umami	Cabin sounds decreases perception of sweetness, saltiness, and sourness. But increases umami intensity ratings of liquid tastants.	Yan and Dando, 2015
White noise (44,100 kHz at 70dB), carbonation, mastication sound, classical music, and shadow (news-music) mix.	Potato chips (Lay's® Original, and a reduced sodium alternative) and carbonated soda samples (Sprite, and Sprite Zero).	Percentage of correct food identification	Consumer discriminatory ability of food was significantly higher when congruent food sounds was played.	Pellegrino et al., 2015
Increased frequency (2 kHz – 20kHz) of live auditory feedback during biting	Potato chips	Intensity of crispness and freshness	Crispiness and freshness of potato chips increases when listening to higher feedback frequency.	Zampini and Spence, 2004
Increased frequency (2 kHz – 20kHz) of live auditory feedback of sparkling water	Sparkling water	Intensity of carbonation	Carbonation of sparkling water significantly increases when listening to carbonation sounds.	Zampini and Spence, 2005
Carbonation, mastication sound, classical music, shadowing (news-music) mix, and white noise	Potato chips and carbonated sodas	Triangle test between potato chips (original versus lightly salted) and carbonated sodas (original versus sugar free)	Auditory masking led to significantly lower scores on the attributes sound and snapping of biscuits.	de Liz Pocztaruk et al., 2011
Increased frequency (2 kHz – 20kHz) of live auditory feedback of apple biting sound	Three apple varieties:	100-point scale measuring apple crispness	Crispiness and hardness of apples were significantly lower in high frequencies of apple biting sound.	Demattè et al., 2014

Table 1 (contd.). Effects of white noise on sensory perception of food.

Two eating sound conditions—loud, and quiet condition produced by the participants	Pretzels	9-point hedonic scale of overall taste, quality, deliciousness, enjoyment, and probability of eating in the future.	Food sound salience significantly decreased quantity of food consumed.	Elder and Mohr, 2016
Study I: Congruent/incongruent sounds (potato chips and coffee) Study II: Pleasant/unpleasant sounds (jazz drum baby laughing, and baby crying screaming)	Study I: Potato chips, and coffee odourant Study II: PEA (rose-like odourant) and 1-butanol	Intensity and pleasantness ratings using visual analog scales (VAS)	Study I: Congruent sounds increases odour pleasantness ratings of congruent food odourant. Study II: Pleasant sounds increases odour pleasantness ratings of PEA and 1-butanol.	Seo and Hummel, 2011
Control, low volume (80 dB) shadow-music, and high volume (100 dB) shadow-music	Alcohol varying in strength (0, 1.9, 3.9, 5.6, and 7.5pct)	Alcohol intensity using visual analog scales (VAS)	Alcohol strength discrimination was significantly lowered in high and low volume shadow music compared to control.	Stafford, Agobiani, and Fernandes, 2013

Musical tones and soundscapes

Implicit associations of tones and food names

The perception of food is not only limited to the food itself but also the sensory information of the food. The summary of the reviewed articles can be found below (Table 2). Some review articles have discussed the effects of sounds and background music on sensory perception (Delwiche, 2004; Stillman, 2002; Verhagen & Engelen, 2006). Crisinel and Spence (2009) investigated the implicit association test (IAT) between tones with different pitch and basic taste. The high-pitched sounds consisted of a C6 (1046.5 Hz) played on a clarinet, a piano, a violin, and a trumpet. The low-pitched sounds consisted of a D2 (73.4 Hz) played on a bassoon, a piano, a cello, and a bass trombone. The food names that sounded sour were correlated with high pitched musical tones, while food names that sounded bitter were associated with low pitched tones. Crisinel and Spence (2010b) further showed the association between names of sweet tasting food with high pitched musical tones, and names of bitter tasting food with low pitched musical tones. In addition, sour taste was matched with sharp and fast sounds. However, in all these studies, food names were used instead of sensory perception of real food samples being consumed.

Influence of tones to taste and flavour using tastants solutions

Crisinel and Spence (2010a) later explored the influence of tones on five basic taste solutions, and seven complex food flavours. High pitched piano tones were closely correlated to sweet and sour tastes (Crisinel & Spence, 2009, 2010b). In contrast, low pitched tones were associated with umami and bitter tastes.

Influence of soundscapes to taste, texture, and perception of food

Crisinel and Spence (2011) generated soundscapes to evoke sweet and bitter tastes. Toffee sample was more bitter with bitter soundscape, and sweeter with sweet soundscape. Carvalho et al. (2015) further showed that bitter chocolate was matched with the bitter soundscape by the majority of participants (83%). However, lower (50%) matching frequency was observed for medium and sweet musical soundscapes. Carvalho, Wang, Van Ee, and Spence (2016) later reported that beer taste can be modulated by listening to specific 'taste' soundscape. Sweet and bitter soundtracks increased the perception of sweetness and bitterness respectively in beer samples. In another study, Carvalho, Wang, van Ee, Persoone, et al. (2016) showed that "creamy" soundscape enhanced creamy and sweet perception of chocolates compared to "rough" soundscape. Interestingly, no effect on the overall enjoyment of chocolates was found, although participants preferred the creamy soundscape.

Table 2. Effects of musical tones and soundscapes on sensory perception

Sound Stimuli	Food Stimuli	Measured Parameter	Research Outcome	References
High pitch tone and low pitch tone	Names of bitter/sour foods	Implicit Association Test between food names and pitch	Sweet taste was associated with high pitch tone, and bitter taste with low pitch tone.	Crisinel and Spence, 2009
50, 75, 100, and 150 Hz sounds varying in vowel height (F1), backness (F2), discontinuity (F3), and spectral balance (F4)	Tastants solutions varying in concentration*	Matching of the tastants with the sounds using four sliders (F1-F4)	Bitterness mapped to lower-frequency sounds.	Simner et al., 2010
Notes from for types of instruments (piano, strings, woodwind, and brass) ranging from C2 to C6	Dark, bittersweet (marzipan filled), and milk chocolate	9-point intensity scale for sweetness, sourness, saltiness, and bitterness	Chocolate sweetness was associated with higher piano pitch frequency. Sourness and bitterness were associated with low intense trombone and complex tone properties.	Crisinel and Spence, 2012
Monotonous pure tone soundtrack based on Crisinel and Spence, 2012 findings.	Cinder toffee	Bipolar sweet-bitter scale.	Bitter soundtrack based from musical tones evoked bitterness, while sweet soundtrack evoked sweetness in toffee samples.	Crisinel et al., 2012
Various musical parameters from guitar, piano, harp instrument with different timbre, brightness, rhythm, and articulation (legato-staccato)	Imagined flavour of orange, lemon, and grapefruit	Frequency count (Yes/No) question towards the soundtrack and imagined flavour matching	Guitar sounds was associated with orange flavour, while piano sound was associated with vanilla flavour.	Bronner et al., 2012
'Woody', 'Grassy', and 'Sweet' audiovisual stimulus	Whisky sample	Liking, sweetness, grassy, and woody ratings of whisky.	'Sweet' soundtrack evoked sweetness, while 'bitter' soundtrack evoked bitterness in whisky samples.	Velasco et al., 2013
Study I: 'Sweet' and 'bitter' soundtracks in matching in terms of taste. Study II: Emotional response (valence and arousal) to the soundtrack samples	Study II: Imaginary sweet/sour/salty/bitter-tasting foods	0-100 agreement scale on the confidence of correct taste and music pairs, and emotional response	Association between sweet, sour, salty, and bitter soundtrack was linked to each corresponding taste	Wang and Spence., 2015

Table 2 (contd.). Effects of musical tones and soundscapes on sensory perception

'Sweet', 'medium', 'bitter' soundtrack	Bitter, medium, and sweet chocolate	Bitter-sweet bipolar scale	Sweet' soundtrack increases sweetness, while 'bitter' soundtrack increases bitterness of chocolates.	Carvalho et al., 2015
Sweet, bitter, and sour soundtracks based on Wang and Spence (2015) study	Belgian beers	7-point hedonic scale in liking, taste (sweet, bitter), contrast-scale (bitter-sweet), and strength	'Sweet' soundtrack evoked sweetness, while 'bitter' soundtrack evoked bitterness in beer samples	Carvalho et al., 2016

Music

Music and food consumption rate

Earlier studies demonstrated the influence of music speed (tempo) on consumption rate. Roballey et al. (1985) and Milliman (1986) reported higher number of bites, and eating speed in a restaurant setting with increasing tempo of music. Listening to faster tempo music was later shown to significantly increase drinking time of soda (McElrea and Standing, 1992).

Volume of background noises also influenced consumption rate. McCarron and Tierney (1989) showed increased total consumption of soft drinks with loud music (90dB) compared to quiet music (70dB). Guéguen and Jacob (2004) further showed that significant number of drinks were ordered in a louder condition (88-91dB). Forsyth and Cloonan (2008) demonstrated that 3.5 drinks were ordered in louder music background compared to 2.6 drinks in the quieter music condition. This study was qualitative and statistical significance of the results were not determined.

Influence of music on food choice and consumer behaviour

Numerous studies had shown that music has also been known to influence food choice. For example, study done by North, Hargreaves, and McKendrick (1999) shows that when German and French was played it increases the sales of German and French wines respectively. In a restaurant setting, music also influenced consumers' dish and beverage choices. Feinstein, Hinskton, and Erdem (2002), demonstrated that when ethnic songs were played in the restaurant, the number of restaurant patron who selected the ethnic dishes increased. In agreement with these studies, Lee, Moon, Rhee, Cho, and Cho (2016) further showed that when French music was played at the restaurant, the orders of French wines significantly increased.

Studies also showed that music can influence consumption of drinks and food. Lindman, Lindfors, Dahla, and Toivola (1986) reported that listening to rock music can increase consumption of alcohol. Jacob (2006) found that playing drinking songs significantly increased time spent in bar, and amount of alcohol consumed. Guéguen, Jacob, Le Guellec, Morineau, and Lourel (2008) similarly showed that bar patrons spent a shorter period consuming alcohol while listening to drinking songs. Listening to music during meals was also shown to decrease depression and anxiety, which in turn promoted food intake in elderly with dementia (Ragneskog, Bråne, Karlsson, & Kihlgren, 1996). Stroebele and de Castro (2006) also reported that the playing background music while eating increases food intake compared to without any music played in the background.

Kontukoski et al. (2015) demonstrated that music influenced the addition sugar into drinks. In their study, participants were provided "sweet" and "sour" classical music pieces. Participants were then prepared a mix of drinks made from sweet and sour fruits (mango. orange, grapefruit, lemon, and pineapple), and honey. The average sugar content of drinks prepared while listening to “sweet” music were higher than the “sour” music condition. In addition, the total acid content were higher in the drinks prepared with “sour” music compared to “sweet” music.

Influence of music on taste perception and flavour perception

Stafford, Agobiani, and Fernandes (2013) showed that low and high volume shadow-music impaired alcohol strength discrimination. Stafford, Fernandes, and Agobiani (2012) further investigated the influence of music, and music with people in the background talking (shadowing task – called shadow-music). Music was found to significantly decrease alcohol strength perception, and increase sweetness of alcoholic drinks higher. North (2012) reported the influence of classical music on the flavour of white and red wines. “Zingy and fresh” music significantly increased the characteristics of “zingy and fresh” of white wine compared to no music. Listening to “powerful and heavy” music, gave red wine samples “powerful and heavy” characteristics. Fiegel et al. (2014) investigated the effect of listening to classical, jazz, hip-hop, and rock music on the perception of chocolate and bell pepper samples. Only overall impression and flavour pleasantness of chocolate significantly increased with jazz music. Table 3 shows the overall summary of the research.

Table 3. Summary of research on the effects of music to taste/flavour perception

Sound Stimuli	Food Stimuli	Measured Parameter	Research Outcome	References
Carmina Burana by Orff (powerful and heavy), *Waltz of the Flowers* from Tchaikovsky's 'Nutcracker' (subtle and refined), *Just Can't Get Enough* by Nouvelle Vague (zingy and refreshing), and *Slow Breakdown* by Michael Brook (mellow and soft).	White and red wine	0 to 10 on characteristic agreement for each of four ratings scales, namely, 'powerful and heavy', 'subtle and refined', 'zingy and refreshing', and 'mellow and soft	Playing music that matched wine attributes significantly increased sensory rating. Wine was perceived as significantly more 'zingy and refreshing' with the 'zingy and refreshing' music	North, 2012
Control, music, shadow (news-repeating sounds), shadow-music	Sweetness and alcohol rating	Intensity ratings using visual analog scales (VAS)	Music increases sweetness and decreases bitterness of alcohol samples.	Stafford et al., 2012
5 music with the characteristics of drops, electro, city, far west, and latino	Selection of 33 beverages ranging from warm drinks to cocktails.	Selection of drinks type (6 type), and 10-point scales on perceived warmth of ambiences.	Participants selected warmer drinks in 'cold' immersive environment In contrast, cocktail drinks were selected in 'hot' immersive environment.	Sester et al., 2013
Edited music piece of four genres (classical, jazz, hip-hop, and rock)	Chocolate and Bell Pepper	15-cm line scales measuring flavour intensity, pleasantness, texture impression, and overall impression	Jazz music significantly increased overall impression of food compared to hip-hop music.	Fiegel et al., 2014
'Sweet' and 'sour' musical pieces based on the selection of classical pieces and a 'sour' musical piece created by Mesz et al., (2012)	Flavoured drink (juice) based on individual selection	Seven-point scale on the food-music and drink-music congruency	'Sweet' music was associated with sweet drinks, while 'sour' music was associated with sour drinks.	Kontukoski et al., 2015

Effect of eating environments

The eating environment where food is consumed contributes to a significant role in the acceptability and perception of food. A review by Stroebele and De Castro (2004) showed that strong influence of ambience on eating behaviour has been largely neglected. Bell, Meiselman, Pierson, and Reeve (1994) demonstrated that an Italian theme in a restaurant resulted in more customers selecting pasta and dessert items, with a higher perceived ethnicity (using their developed "degree of ethnicity" scale) and acceptance of Italian food items. Meiselman, Johnson, Reeve, and Crouch (2000) further showed that different eating locations (i.e., laboratory, training restaurant, and dining hall) influenced food acceptance. In their study, participants rated the liking of all food samples (chicken fettucine, salad, vegetable, bread, dessert and beverage) higher in restaurant setting, followed by laboratory, and dining hall. Petit and Sieffermann (2007) similarly demonstrated that liking and consumption were dependent on sensory testing locations (laboratory, natural eating environment, and situational laboratory). In their study, coffee was significantly more liked and consumed in the natural eating environment compared to the laboratory environment. Immersive environments are defined as a simplified simulation introduced to observe people's behaviour (Sester et al., 2013). These environments are widely used in the business sector to understand consumer purchase behaviour (Daugherty, Li, & Biocca, 2005). Immersive conditions can increase the liking of wine (Hersleth, Mevik, Næs, & Guinard, 2003), as-well-as salad, pizza and iced tea (King, Weber, Meiselman, & Lv, 2004). In a recent study, virtual coffeehouse (i.e., an immsersive environment) showed to have higher discrimination and was a reliable for coffee liking in comparison to traditional sensory booths (Bangcuyo et al. 2015).

Proposed theories explaining the influence of auditory cues on food perception

Background noise, environmental sounds, and music can influence mood, which can in turn affect food perception. Several mechanisms that have been proposed to explain how sound can influence food perception is discussed below.

Auditory-olfactory transduction

The transduction theory of audio-taste crossmodality was proposed by Woods et al. (2011) to explain changes in taste perception with auditory cues. The proposed theory assumed that the interaction between sound and taste might be similar to other sensory cortical structures (Schroeder and Foxe, 2005). A study by Wesson and Wilson (2010) showed that when a 78dB sound was played, 19% of rat olfactory neurons were activated, and 29% of these were altered when the auditory stimulus were played. Woods et al. (2011) further postulated that these changes in neurons while listening to sound may possibly influence taste neurons as well.

Contrasting effect

The contrasting effect occurs when there is diminishment or enhancement of a stimulus due to a greater exposure of other stimulus (Rossotti, 1985). Woods et al. (2011) proposed that the contrasting effect that might occur when participants were exposed to loud background noise. They found that loud background noise diminished the sensory perception of sweetness and saltiness of savoury and sweet snacks.

Attention and distraction

Attention to food during consumption might be interrupted by the other sensory cues. The attentional-distraction theory proposed that an incoming sensory perception can be diverted or reduced by attention to a different sensory stimulus. Some studies have also suggested that music can act as a distraction, which influence consumption behaviour. Stafford et al. (2012) showed that music was a distraction that resulted in increased sweetness, and lower discrimination of alcohol strength. Stroebele & de Castro (2006) further confirmed that listening to music became a distraction and increased food intake.

Interestingly, time is perceived to pass more slowly in the presence of music, thereby encouraging consumption. Milliman (1986) reported that playing slow music distorted participants' perception of time and significantly increased consumers' time at the table, and amount of bar purchases. They proposed that slow music created a more relaxing environment that in turn created positive affect in the participant.

Pavlovian conditioning

Food sounds like crispness can influence food quality, and pleasantness perception. Zampini & Spence (2004) demonstrated that increasing the frequency of potato chip eating sound and water sound increased the perceived crispness, and freshness of potato chips, and carbonated water respectively. In another study, carbonated beverages were perceived to be more carbonated while listening to higher frequency sounds of carbonation (Zampini & Spence, 2005). They explained their results by using the Pavlovian conditioning theory (Pavlov, 1927). In relation to the Pavlovian conditioning theory, it may have seemed that there is a learning/conditioning response of auditory stimuli in relation to crispness and freshness of food (Zampini & Spence, 2005).

Transference theory

The transference theory is expressed as the transfer of a hedonic valence of a stimulus to another stimulus (Cheskin, 1972). Seo and Hummel (2010) reported that congruent sounds (i.e. Christmas carol sound) increased the pleasantness of the cinnamon odour. In addition, pleasant sounds (i.e. baby laughing/jazz drum) increased pleasantness ratings of rose odour. The authors proposed that the hedonic valence of sounds were transferred to odours. Carvalho, Wang, Van Ee, and Spence (2016) investigated the effects of sweet, bitter, and sour soundtracks developed from a study by Mesz, Trevisan, and Sigman (2011) on the taste of beer samples. They showed that when listening to a sweet soundtrack beer samples (*Taras Boulba*, and *Jambe de Bois*), sweetness significantly increased. Listening to a bitter soundtrack significantly, on the other hand increased bitterness in *Zinnebir* beer samples. The authors proposed that participants transferred their music experience to sensory perception of the beer samples.

Emotion

Emotion and mood can affect taste and flavour perception of food. A study by Heath, Melichar, Nutt, and Donaldson (2006) reported lower sweetness sucrose threshold and higher bitterness threshold in a heightened positive mood. In a related study, Platte et al. (2013) demonstrated the influence of mood on taste perception. Participants rated taste intensity of five basic tastants and a fat tastant solution. The bitter solution (quinine sulphate) was perceived to be more bitter with negative mood, and sucrose solution sweeter under a positive mood condition.

Arousal

Listening to unpleasant sounds (airplane noise, baby crying) can increase arousal ratings (Gomez & Danuser, 2004). Guéguen et al. (2008) showed that loud level of background music increased the number of drinks ordered and gulps per drinks, but decreased the time spent drinking a glass of the alcohol. The authors explained that the changes were attributed to the arousal effect of loud background noise. The high sound level of background music resulted in a high level of arousal, which lead to enhanced behavioural response to drinking alcohol.

Temporal measures in sensory science

Static sensory methods such as sensory profiling, and generic descriptive analysis (Cliff & Heymann, 1993) requires a trained panel to perform overall judgment of a product during consumption with no perceived changes in sensations overtime taken into account. Some of the common sensory methodologies that measure food perception over time will be discussed.

Time Intensity

Time Intensity (TI) provides the evaluation of perceived sensory intensity over time. TI plots the intensity profile of food and shows differences between products overtime from the moment of product evaluation, where these sensations would increase and eventually decrease in their perceived intensity (Lawless & Heymann, 2010). TI mainly used in singular gustatory attributes (Clark & Lawless, 1994; Ott, Edwards, & Palmer, 1991; Peleg, Gacon, Schlich, & Noble, 1999; Valentová, Skrovánková, Panovská, & Pokorný, 2002), and texture perceptions (Guinard & Marty, 1995; Brown, Gerault, & Wakeling, 1996); Hyvönen, Linna, Tuorila, & Dijksterhuis, 2003). However, the use of this method is limited to one sensory attribute measured at a each given time.

TI utilises a single scale, which measures a single attribute intensity over a specified time. This comes with a risk of halo dumping effect as reported by Clark & Lawless (1994) who showed increased rating of sweetness intensity when only sweetness was rated. Participants' ratings was shown to be significantly higher when presented with taste and flavour. To address the shortcoming of a halo dumping effect, methods like Dual Attribute Time Intensity (DATI) with a dual time intensity scale (Duizer, Bloom, & Findlay, 1996) and Multiple Attribute Time Intensity(MATI) with multiple time intensity scales (Kuesten, Bi, & Feng, 2013) have been developed.

There are no general consensus on the optimum number of judges in the TI method. Previous studies have reported number of participants to be 13 with no repetitions (Larson-Powers & Pangborn, 1978), 10 participants (Cliff & Noble, 1990), 18 participants with 2 repetitions (Peleg et al., 1999), and 16 participants with no repetitions (Pineau et al., 2009). However training of panellists are important. Peyvieux and Dijksterhuis (2001) stated that participants' individual variance should be taken into account during panel training to provide TI signature curves. The authors recommended the use of Generalized Procrustes Analysis (GPA) to assess possible outliers within panel's repetitions, and Principal Component Analysis (PCA) to observe between panel inconsistencies in TI measures.

Temporal Dominance of Sensations

The Temporal Dominance of Sensations (TDS) methodology is used to explore dominant sensations of specific food overtime, by qualitatively identfying and quantitatively rating the chosen sensory attributes. The definition of dominant is "the sensation that captures participants attention, the most striking, or new sensation that pops up at a given time" (Labbe, Schlich, Pineau, Gilbert, & Martin, 2009; Pineau et al., 2009).

The TDS method does not have any specific ruling on the number of participants. However, it is recommended that there are at least 30 evaluations per product (Di Monaco et al., 2014). Other TDS studies have used 9 trained participants (Albert, Salvador, Schlich, & Fiszman, 2012), 13 participants (Dinnella, Masi, Naes, & Monteleone, 2013), and 16 trained participants (Meillon et al., 2009).

TDS Data analysis

Data collected using temporal methods are usually collected as intensity measurements of each sensory attribute over a set time duration. In the TDS method, attributes are the exclusively dominant sensory sensations. Results using temporal methods are usually presented as curves to show the intensity or dominance rate of sensory attributes overtime per sample. In general, the x-axis of the curve will show the time, eating period, bites, or standardized time. The y-axis will show the average intensity of all sessions (all replications) or the dominance rate. Attribute curves are constructed by either averaging the intensity, or calculating the dominance rate across participants. Bezier or Spline smoothing of the curves is also a common practice in presenting temporal data (Pineau et al., 2009). TDS curves also has the option that standardizes time, where the set duration of mastication period during the trial will be converted to 0-100% Standardised Time (ST) in order to magnify and provide higher resolution of the temporal data (Di Monaco et al., 2014).

TDS dominance rate can be expressed as the proportion of the dominant attribute in over a specified period. Dominance rate is defined as the average number of citations over trials. This was used to measure consensus among participants (Pineau et al., 2009). For example, if there is only one attribute that can be selected by one participant and there are ten participants in the panel, each participant that selected that attribute will contribute to 10% (1 out of 10) of the dominance rate at a specific time period. Hence, if the more participants agrees with the specific attribute, the higher dominance rate becomes.

The proportion (percentage) of participants selecting the dominant sensory sensation can be used to present TDS data (Pineau et al., 2009) (Figure 1). The proportion of participants selecting the dominant sensory attributes is then later plotted overtime called dominance curve (Figure 2). This dominance curve can be smoothed using either the Spline or Bezier smoothing algorithm Significance and chance levels are added horizontally in the dominance curve (Pineau et al., 2009). The chance level (P_0) shows the rate of an attribute that was selected by chance and is calculated as the inverse of the number of sensory attributes. While significance level (P_s) represents the binomial proportion confidence interval (Pineau et al., 2009).

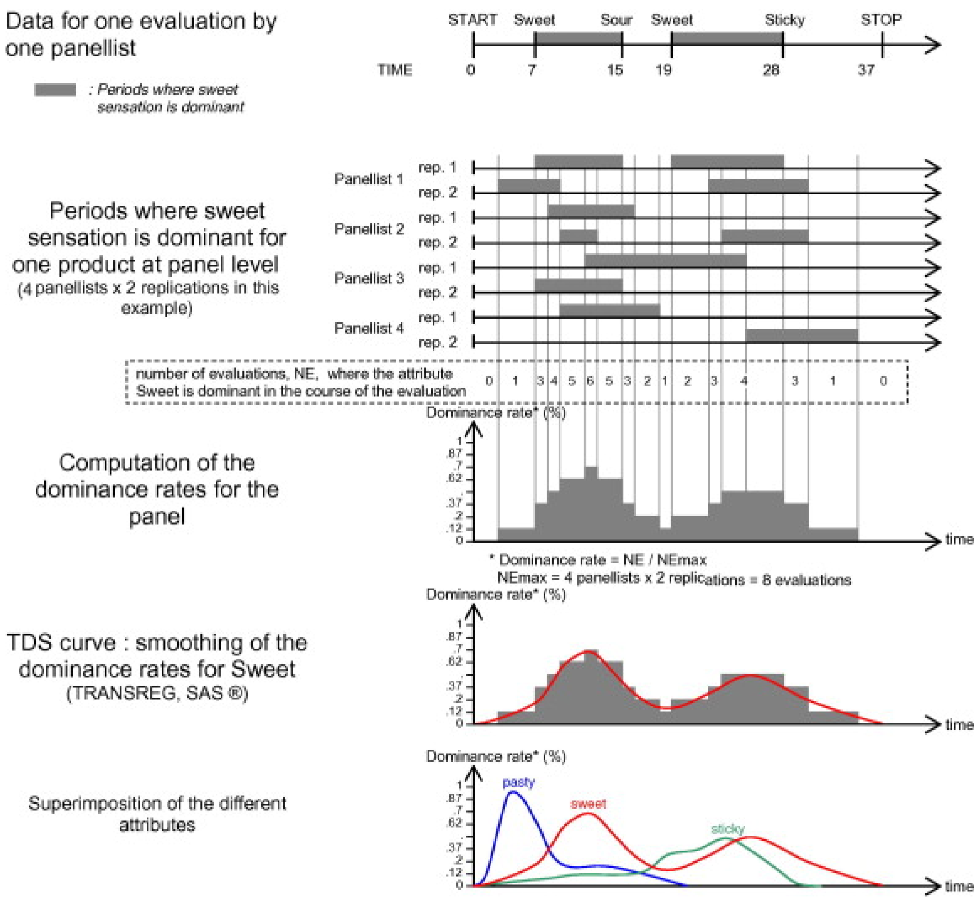

Figure 1. Summary of TDS panel dominance of curve construction (Pineau et al., 2009).

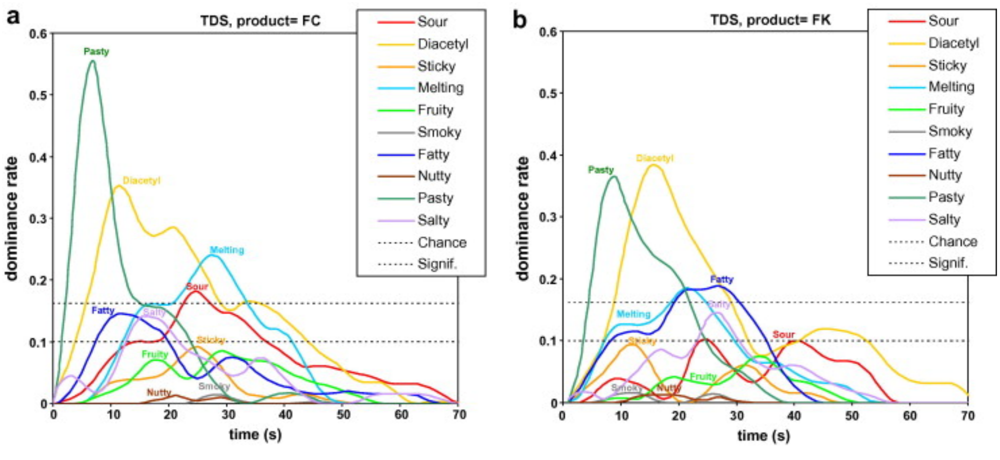

Figure 2. Example of TDS curves with chance and significance levels (Pineau et al., 2009).

Multivariate approaches in TDS

One of the multivariate approach used to analyse TDS data is to process the data of total duration of each TDS sensation to Canonical Variate Analysis (CVA). CVA offers higher resolution of the data as it uses the measures of each panel instead of using the average data values in the case of Principal Component Analysis (PCA). In addition, Hotteling Lawley MANOVA can be carried out to see the overall significant difference between the products, and 90% Confidence Ellipses can be plotted on the two dimensional plot to observe the significant differences between products centroids. If the two ellipses do not overlap, the product is significantly different. If it overlaps, the products are significantly different to each other. This method has been used in other studies utilising TDS, for example in chocolate (Jager et al., 2014), and cheese (Thomas, Visalli, Cordelle, & Schlich, 2015). Overall, CVA provides a valuable tool in product characterisation using TDS.

Temporal Check All That Apply (TCATA)

In Temporal Check All That Apply (TCATA) participants are encouraged to select more than one attribute, and to deselect attributes if when not applicable (Castura et al., 2016). Participants are allowed to select or unselect the attributes any time during product evaluation. TCATA utilises the basic principles of constructing TDS curves, where the raw data of each selected attribute will be aggregated in order to calculate citation proportions for each sensations (Figure 3). Smoothing is also applied in TCATA curves using the Spline algorithm (Späth, 1974). There are no chance and significance levels in the TCATA curves, as more than one attribute can be selected whenever applicable. A reference curve (heavier coloured curves) can be plotted in TCATA curves instead. The two-sided Fisher–Irwin test (Fisher, 1935; Irwin, 1935) can be used to further indicate whether the sensory attribute was significant at each given time point. The reference curves indicate differences in citation proportions of one product compared to other products (Figure 4). In addition, multivariate approach using correspondence analysis can be used to explore product attribute trajectory (Figure 5).

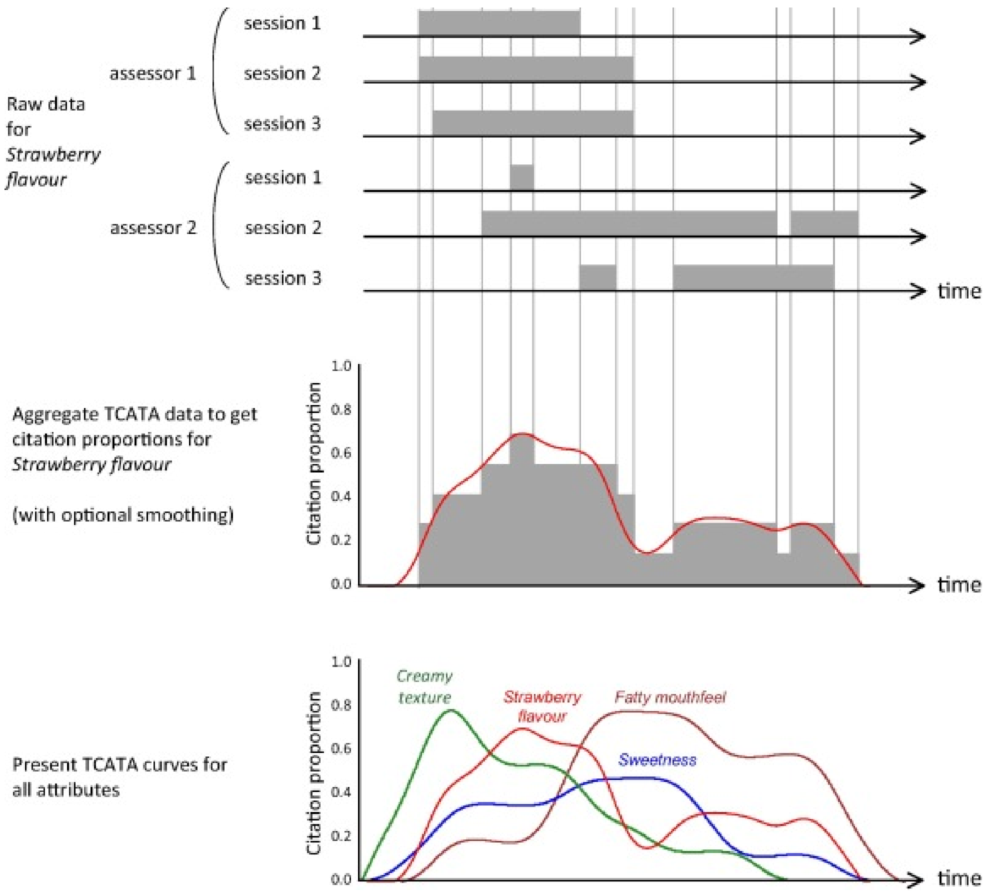

Figure 3. Summary of TCATA panel curve construction (Castura et al., 2016).

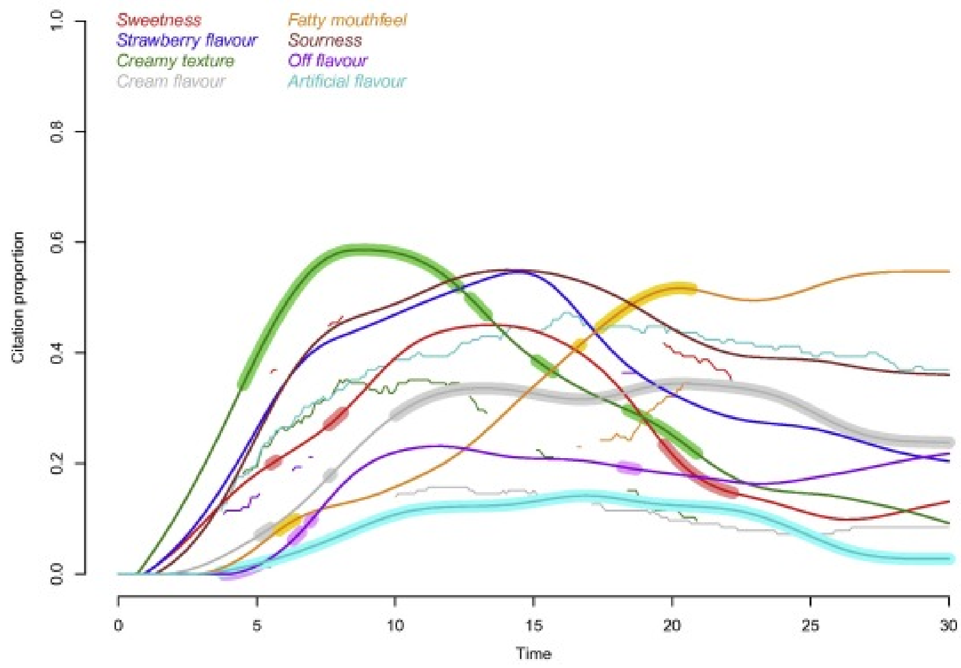

Figure 4. Example of TCATA curves with heavier lines added to each curve. The bolded lines were calculated using Fisher-Irwin test (Castura et al., 2016).

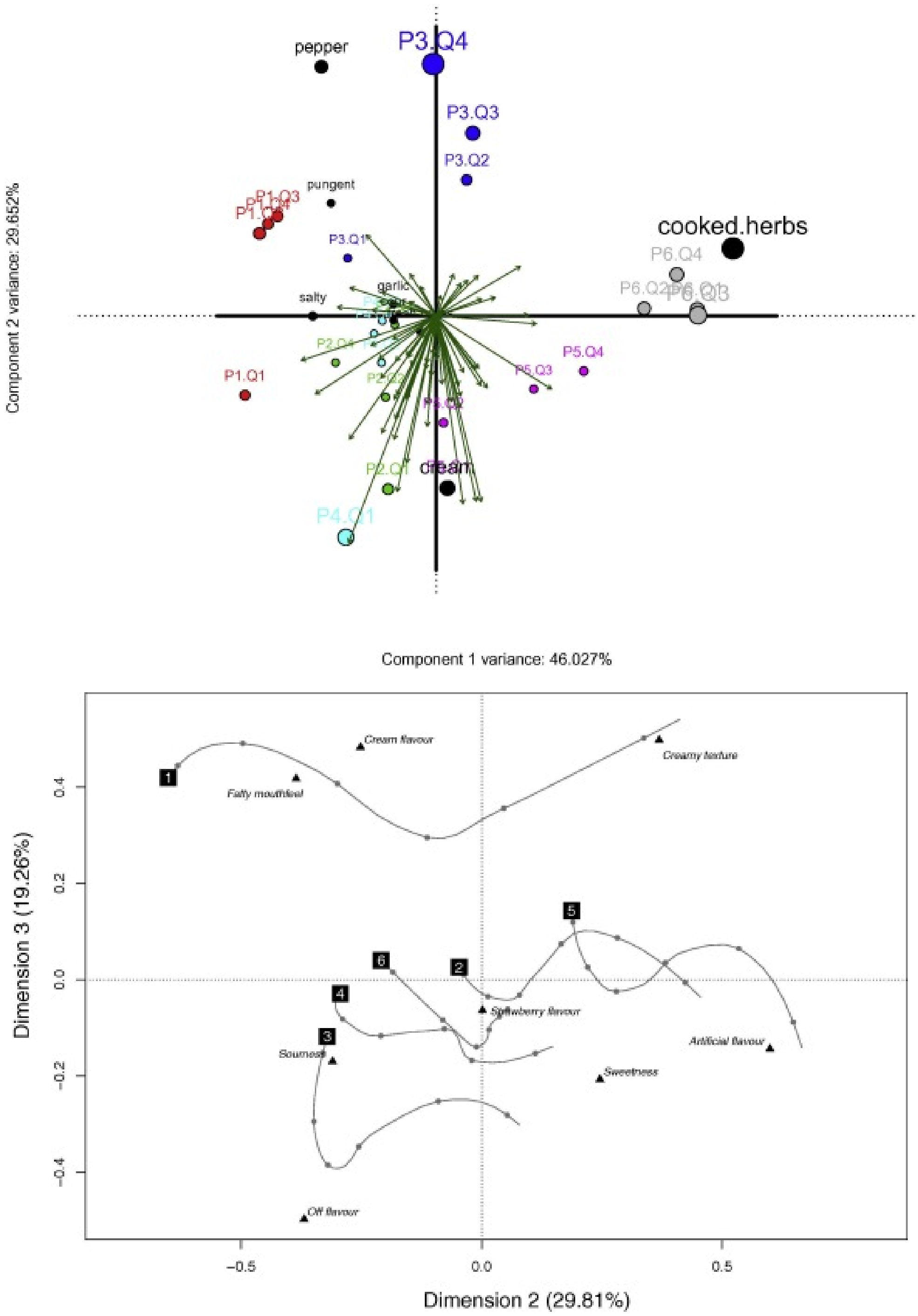

Figure 5. Correspondence Analysis (CA) oral trajectory modelling from TCATA data. Each vector represents sensory attributes and each product loadings corresponds to the total CATA counts for each sensation (Meyners, 2016) and (Castura et al., 2016).

Measurement of emotions

Self-reported measures of emotion during food consumption

Measuring emotions in food have been an area of interest lately. Various research have adapted scales from the psychology field, mainly focusing on the valence dimension (positive and negative emotions) to measure self-reported emotions associated with foods. The measures of emotion in food have been directly associated with the emotional experience while eating (i.e. emotion questionnaire was provided after eating food), and questionnaires were usually administered after food consumption.

Studies on food have mainly utilised existing list of emotions from other studies (Desmet & Schifferstein, 2008) or moods from pre-existing psychology mood scales, namely Positive and Negative Affect Schedule (PANAS), on various food stimulus (Churchill & Behan, 2010; King & Meiselman, 2010; King, Meiselman, & Carr, 2010) to measure consumers' emotional response. However oversimplification of emotion measurements using PANAS focusing solely on valence dimension may not be well suited for food related emotions (Posner, Russell, & Peterson, 2005). Recent studies have used basic states of emotions to measure emotions during food consumption (Matsumoto & Ekman, 2009). This is however inappropriate as although disgust and joy can be evoked by food stimulus, other emotions such as fear, anger, and sadness are less likely to be reported (Laros & Steenkamp, 2005).

After examining the inappropriateness of some of the emotion terms in psychology literatures, King and Meiselman (2010) derived their emotional lists from existing publications and direct consumers feedback to measure emotions evoked by or related to food. In their study, consumers evaluated 81 terms that were clustered to 2-3 terms per group based on similarity of definitions called the EsSense Profile. The EsSense Profile were categorised into positive, negative, or unclear. The EsSense Profile has been used in the testing of chocolate and potato chips (Cardello et al., 2012), breakfast drinks (Gutjar et al., 2015), beer (Chaya et al., 2015). Cardello et al. (2012) found that chocolate evoked more intense emotional response compared to potato chips. Gutjar et al. (2015) profiled emotions evoked by drinking seven different breakfast drinks using PrEmo and EsSense Profile. Breakfast drinks that evoked higher positive emotions showed higher ratings of liking. In another related study Chaya et al. (2015) developed consumer emotion terms to measure emotional responses to ten different beer samples (i.e. happy, sweet, bitter, high alcohol). The consumer emotion terms differentiated the samples based on high alcohol content that was associated with negative emotions.

Jager et al. (2014) was the only study to measure temporal aspects of emotions using Temporal Dominance of Emotions (TDE). With TDE, participants indicated their dominant emotion perception over a period of time. In their study, various chocolate samples (i.e. fruit, dark, mint) were profiled using

TDS and TDE, and a relationship was drawn using CVA. Participants associated the high cocoa content chocolate with dry and cocoa sensory sensations that was closely related to negative emotions. On the contrary, fruity chocolates (i.e. orange and blueberry) described as having sweet and fruity sensations were associated with positive emotions.

Although the use of self-reported emotion measures in food is increasing, there are some concerns in measuring self-reported emotions that has been overlooked. For example, participants with high social desirability might be less willing to report negative emotional states, and may create invalid reports of their emotions (Paulhus & John, 1998). Another concern would be alexithymia, a condition where participants may be unable to identify or describe emotions that they are experiencing. Individuals with alexithymia are limited in expressing their emotional expressions in self-reports (Lane, Ahern, Schwartz, & Kaszniak, 1997). The use of other objective measures such as ANS response measurements, or behaviour measures using fMRI have been proposed in order to understand how the brain processes the integration between emotion and sensory information.

Measurement of emotions using autonomic measures

The autonomic nervous system (ANS) modulates our peripheral organ functions. This system includes the sympathetic nervous system, which is responsible for activation, and parasympathetic nervous system, which is responsible for relaxation. ANS activity is linked to emotional processing, and is also an indicator of bodily function (i.e. digestion), attention, homeostasis, etc. Common ANS measures include electrodermal and cardiovascular responses. Electrodermal response is usually measured using Skin Conductance Level (SCL) or short-duration skin conductance responses (SCR). Common cardiovascular responses include heart rate (HR), heart rate variability (HRV), blood pressure (BP), cardiac output (CO).

Bradley and Lang (2000b) proposed that ANS activity should be viewed in broader dimensions such as arousal. For example, SCL showed positive linear correlation with self-rated arousal of a stimuli (Lang, Greenwald, Bradley, & Hamm, 1993). Numerous findings (Bensafi et al., 2002; Hagemann et al., 2003) supported that ANS responses can index emotional levels accordingly based on arousal dimension. However, not all ANS measures corresponds to a singular affect dimension (i.e. arousal). Kreibig, (2010) showed that the interactions between multiple ANS responses correlate positively, negatively, or concurrently with each other. For example, the decrease in HR may be taken as a decrease in sympathetic activity. However, it can be accompanied with an increase in other ANS measures (namely SCL) linked with sympathetic activity (Kreibig, 2010). Therefore, it is recommended to measure multiple dimensions for the ANS response to investigate whether there is an interaction between ANS measures (Cacioppo et al. 2000). Kreibig, Wilhelm, Roth, and Gross (2007) utilised different ANS responses to differentiate emotional states induced by films (fear and sad). The authors concluded that multiple ANS measures (cardiovascular, electrodermal, and respiratory) contributed resulted in higher resolution for predictions of discrete emotional states.

Using ANS measures to quantify emotions evoked by music

Music can evoke a variety of emotions. Numerous ANS measures have been reported to characterise emotions evoked by music (Table 4). Nyklíček, Thayer, and Van Doornen (1997) demonstrated the effect of *happy*, *serene*, *sad*, or *agitated* music excerpts, and found significant differences in respiratory responses. They reported that the respiration rate was the highest in high arousal music excerpts (happiness, and agitation), followed by low arousal music excerpts (serenity, and sadness). However the Finger Pulse Amplitude showed the highest response while listening to serenity and sadness music pieces, followed by agitation and happiness music pieces

Krumhansl (1997) used classical music to evoke emotions in their study. Classical music that represented *sad*, *fear*, and *happy* emotions were selected.

Their study showed that cardiovascular, electrodermal, and respiration responses were significantly different with music excerpts. Listening to *sad* music resulted in the highest changes in Heart Rate (HR), blood pressure, Skin Conductance (SC), and Finger Temperature (FT) while. *Fear* music excerpts showed large change in cardiovascular function. *Happy* music excerpts resulted in large changes in respiration measures. This finding was supported by a study by Etzel, Johnsen, Dickerson, Tranel, and Adolphs (2006) who selected 12 music clips to induce *happiness*, *sadness*, and *fear*, and measured cardiovascular (heart rate) and respiration (respiration rate). They found that heart rate decelerated with *sad* music clip, and accelerated in both *fear* and *happy* music clips. In addition, respiration rate was the longest for *sadness* followed by *fear*, and the least for *happiness*.

In another approach, Salimpoor, Benovoy, Longo, Cooperstock, and Zatorre (2009) investigated the ANS responses of self-selected music varying in valence (low and high pleasure). Skin conductance, and heart rate significantly increased with the function of valence (neutral-low-high pleasure music). A significant increase was observed only for respiration rate when listening to neutral music compared to low pleasure and high pleasure music. BVP amplitude and skin temperature decreased with the function of valence. They found that electrodermal measures was considerably the best predictor for emotional arousal with responses positively correlated with self-rated pleasure across the low-pleasure to high-pleasure music.

Various environmental sounds such as mechanical sounds and bird twitters can also modulate ANS responses. Yanagihashi, Ohira, Kimura, and Fujiwara (1997) reported a significantly lowered High Frequency (HF%) HR response while listening to unpleasant mechanical sounds compared to listening to pleasant bird twitter. This response had a positive correlation with comfort (valence), The respiratory rate for mechanical sounds were significantly higher than bird twitter sound, with positive correlations with ratings of awakening (arousal). Their results suggests that unpleasant sounds decreases para-sympathetic nervous system responses.

Table 4. Summary of research on the ANS responses evoked by music

Sounds or music	Measured Parameter	Research Outcome	References
12 music clips to induce fear, sadness, or happiness (4 music clips representing each emotion)	Heart rate, and respiration rate	Cardiovascular measures decreases with sad music, and increases with fear and happy music. Respiratory measure was longest for sad music followed by fear and the least for happy music.	Etzel et al., 2006
6 music clips to induce sadness, or happiness (3 music clips representing each emotions)	Heart rate, blood pressure, respiration rate, skin conductance, Zygomatic, and corrugator muscles activity	Happy music evoked higher diastolic blood pressure, electrodermal activity, and zygomatic activity. Respiration rate was faster with stimuli presented at faster music tempo.	Khalfa et al., 2008
6 music pieces chosen to represent each of three emotions: sad, fear, and happy.	Cardiac, vascular, electrodermal, and respiratory measures	The sad excerpts showed significant changes in heart rate, blood pressure, skin conductance and temperature. The fear excerpts showed significant changes in cardiovascular function. The happy excerpts showed significant changes in respiration measures.	Krumhansl, 1997
12 music excerpts, previously selected as being happy, serene, sad, or agitated (each of these four emotions was represented by 3 music excerpts)	Electrocardiogram, Impedance cardiogram, Phonocardiogram, and respiration	Respiration measures was highest in high arousal music. Cardiovascular measures was highest in low arousal music.	Nyklicek et al., 1997
Participants' self-selected low pleasure, high pleasure, chill, and neutral music	Skin conductance, heart rate, BVP amplitude, skin temperature, and respiration rate	Increase was observed only for respiration rate while listening to neutral music compared to low pleasure and high pleasure music. BVP amplitude and skin temperature was shown to decrease with the function of music valence	Salimpoor et al., 2009

Measurements of ANS for food

Studies have been carried out to measure ANS responses to visual, odour, and taste of liked and disliked foods (de Wijk, Kooijman, Verhoeven, Holthuysen, & de Graaf, 2012), and to predict sensory liking of breakfast drinks (de Wijk, He, Mensink, Verhoeven, & de Graaf, 2014), and liking of juices (Danner, Haindl, Joechl, & Duerrschmid, 2014). de Wijk et al. (2012) selected measured ANS and facial responses towards liked and disliked foods. ANS responses were measured when participants assessed food in terms of appearance, odour, and taste. Disliked foods showed a significant increase in skin conductance measures compared to liked foods, and showed a significant increase in *sadness*, *disgust*, and *angriness* in terms of facial expressions. A significant increase in SCRs for disliked foods was found with children, while young adults showed significant decrease in SCRs. Children also had a higher heart rate response when tasting liked food, while no significant differences were observed with adults. A significantly higher finger temperature was found for foods that were liked compared to foods that were disliked. The authors proposed that the ANS patterns of disliked and liked foods were similar to the ANS patterns of negative and positive emotions respectively.

In an extension of their study (de Wijk et al., 2014), ANS measures were used to distinguish the differences of a set of breakfast drinks similar in terms of liking. In addition, an attempt to explore the association of ANS, and emotion using facial expression in terms of liking and intensity was carried out. The set of breakfast drinks were exposed to the participants five times. ANS measures, facial expressions, liking, and intensities were recorded. Increases in HR, FT, and neutral facial expressions were positively correlated with liking. Reduced HR, FR, and negative facial expressions of *sadness, anger*, and *surprise* were associated with negative emotions. In another related study, Danner et al. (2014) showed that juice samples that were disliked, showed higher SC response compared to liked sample. Facial expressions further categorised liked and disliked samples. Negative facial expressions and less neutral expressions were shown for the disliked samples, while liked sample showed very little changes.

The most fundamental study on five basic tastant solutions was done by Rousmans, Robin, Dittmar, and Vernet-Maury (2000), who measured five ANS parameters. All ANS parameters showed significant differences in terms of the primary taste. They reported that mineral water had the weakest ANS response, followed by sucrose, sodium chloride, citric acid, and quinine sulfate tastant solutions. The authors proposed that the distinct ANS changes were related to the innate liking of the taste. Sweet taste induced weakest ANS response as it is innately-accepted, while bitter taste showed the strongest ANS response as it is innately-rejected.

Chapter 4. The influence of auditory and visual stimuli on the pleasantness of chocolate gelati

Kevin Kantono[a], Nazimah Hamid[a*], Daniel Shepherd[b], Yi Hsuan Tiffany Lin[a], Svetlana Yakuncheva[a], Michelle JY Yoo[a], Gianpaolo Grazioli[c], and B.Thomas Carr[d,e]

[a] School of Applied Sciences, Auckland University of Technology, Private Bag 92006, Auckland 1142, New Zealand

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

[c] Giapo Ice Cream and Research Kitchen, 279-281 Queen St., Auckland 1010, New Zealand

[d] Carr Consulting, 1215 Washington Ave. Suite 203, Wilmette, IL 60091, USA

[e] Charles Sturt University, Wagga Wagga, NSW, Australia

*Correspondence to be sent to: Nazimah Hamid, School of Applied Science, Auckland University of Technology, Auckland, New Zealand. Email: nhamid@aut.ac.nz

Abstract

Unrelated auditory cues may alter gustatory and hedonic perceptions to food, but it is unclear whether similar effects will be observed with congruent eating-environment sounds. This is the first experimental work to demonstrate how different eating-environment sounds, varying in quality, may influence pleasantness of food samples. In this study, trained participants (n=90) were separated into two balanced groups. The first group provided temporal pleasantness measurements during consumption of three different chocolate gelati while listening to various eating-environment sounds, and a silent control condition. This procedure was followed using a second group though with the provision of pictures related to the eating-environment sounds. Both psychoacoustical and psychological measures of sound quality were associated with gelati pleasantness. Combined audiovisual cues further amplified pleasantness ratings compared to auditory cues only. The results are further explained in terms of the effects of mood and arousal on sensory perception. Findings from this study may assist in elucidating the real life implications of the effect of sounds on food pleasantness.

Keywords: crossmodal, time intensity, gelato, pleasantness

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Introduction

The multisensory nature of eating is an understudied but crucial element that can influence eating behaviour. Pellegrino et al. (2015) showed that only 3.7% of the participants in their study preferred eating in silence, whilst the rest preferred eating in conditions with sounds in the background. Fell (2012) further inferred that our preference of eating with noise could be due to our increased exposure to machines and technologies in our daily lives. Auditory cues such as environmental sounds and music can be used to enhance gastronomic experiences. Recent studies showed that factors from top-down processes such as expectancy (Verhagen & Engelen, 2006), complex emotions (Canetti, Bachar, & Berry, 2002), and contextualization (Meiselman et al., 2000) can influence food perception. Sounds related to food such as crispness or crunchiness have been found to influence the texture perception of both wet and dry food samples (Demattè et al., 2014). Sounds that are completely unrelated to food such as music (Fiegel et al., 2014), and white noise (Woods et al., 2011) can also alter sensory perception of food.

Woods et al. (2011) reported that background noise influenced not only the textural perception of food but also its taste. Playing loud white noise consistently decreased liking and taste perception across a range of sweet and savoury food samples. Background music has been shown to influence taste perception of alcoholic beverages. Stafford et al. (2012) demonstrated that exposure to music led to higher sweetness ratings of alcoholic beverages compared to control and other sound conditions (i.e., a repeating news story, and a combination of repeating news story and music). These studies support the sensory dominance theory that explains how audition can dominate over certain gustatory/olfactory processes during the perception of food (Woods et al., 2011).

It has long been known that acoustic and visual cues can activate appetitive and defensive motivational circuits in the brain (Lang, Bradley, & Cuthbert, 1998; Lang, Bradley, Fitzsimmons, et al., 1998). Affective dimensions of valence (i.e., pleasantness) and arousal elicited by naturally occurring sounds (e.g., church bell, beer, *etc*.) have been investigated by Bradley and Lang (2000a). Sounds that are low in valence (i.e., unpleasant) may induce higher anxiety (Martin-Soelch, Stöcklin, Dammann, Opwis, & Seifritz, 2006), while sounds that produce higher levels of affective arousal may induce greater emotion response (Bradley & Lang, 2000a). In addition, dominating sounds have been shown to direct attention (Frith & Allen, 1983; Medvedev, Shepherd, & Hautus, 2015). One study incorporated waiting time as an attentional-distraction factor in order to investigate food choice and enjoyment (Nowlis, Mandel, & McCabe, 2004). A review by Macht (2008) reported that emotions varying in valence influenced eating behaviour. Negatively valent emotions such as anger, fear, and sadness may increase impulsive eating, increase consumption of junk food, and decrease food pleasantness. In contrast, positively valent emotions such as joy and other positive emotions can increase food pleasantness and consumption of healthy foods (Macht, 1999; Macht, Roth, & Ellgring, 2002).

The Pleasure-Arousal-Dominance (PAD) model of emotion, commonly known as the Mehrabian Russel (M-R) model (Russell & Mehrabian, 1977), has been applied in numerous business and retail consumer studies (Yani-de-Soriano & Foxall, 2006). For example, Jang and Namkung (2009) utilized the extended M-R model to investigate consumer's evaluation of restaurant quality. Using structural equation modelling they found that atmospherics and service enhanced positive (i.e., approach) emotions, while food quality acted to relieve negative (i.e., avoidance) emotional responses.

Vision has been shown to dominate our spatial perception even during the multisensory integration of audiovisual systems (Bulkin & Groh, 2006). Stein, London, Wilkinson, and Price (1996) demonstrated that a brief, broad-band auditory stimulus significantly enhanced the perceived intensity of an LED intensity. The effect was most pronounced at the lowest visual intensities, and was evident regardless of the location of the auditory cue. In addition, Baumgartner, Lutz, Schmidt, and Jäncke (2006) reported that pictures accompanied by matching music evoked higher emotional responses (e.g., *fear, happy, sad*) compared to pictures presented in isolation. Photographs of different restaurants were reported to influence cognitive representations such as costs, food quality, and ambience (Cherulnik, 1991). In another study, participants rated affective dimensions higher when exposed to atmospheric cues associated with elegant hotels compared to fast food cues (Stapel, Koomen, & Velthuijsen, 1998). Consumption contexts can also influence preference rankings and liking of coffee (Bangcuyo et al., 2015). Coffee samples were rated higher in immersive environments accompanied by congruent audiovisual stimuli compared to a laboratory setting. Our study will investigate the effect of audiovisual stimuli of different eating environment on temporal food pleasantness.

Eating is a dynamic process that can be investigated using the time intensity (TI) method (Veldhuizen, Wuister, and Kroeze (2006). By adopting TI approaches, we hypothesize that there will be differences in hedonic ratings for different eating-environment sounds during food consumption. Hence the aim of this study is to investigate the effect of background café sounds (with and without visual cues) on the temporal pleasantness of chocolate gelati (dark chocolate, bittersweet, and milk chocolate). The affective state (arousal, valence, and dominance) of participants while consuming gelati will also be measured to help explain changes in pleasantness.

Materials and methods

Ethics Statement

Ethics approval by the Auckland University of Technology Ethics Committee (AUTEC 12/79) has been obtained for this study. Participants provided written consent prior to commencement of the study.

Participants

Ninety participants (42 males, 48 females) between 21 and 43 years of age participated in this study (Mean age = 29 years; SD age= 5 years). Participants were students and staff members from three universities based in Auckland, New Zealand. They were recruited online and received a voucher for their participation. The participants were non-smokers, and did not suffer from any eating disorders and health problems associated with food. The trials were carried out between 2-3 pm weekdays, and replicated twice. Participants were then randomly assigned to each test condition (audio only, or audiovisual condition) with balanced number of participants (n = 45) for each test condition.

Background noise stimuli

Background noises were recorded over lunch hour (13:00 – 14:00), on the same day of the week (Monday) in three different settings, a café, a fast food restaurant, and a bar. The Root Mean Square amplitudes of the audio samples were standardized to an internal reference to achieve equivalent sound pressure levels across all audio samples, and later scaled to 70 dB SPL, using a Brüel and Kjær sound level meter (Nærum, Denmark). This is considered a reasonable volume to present the sounds, while avoiding amplitudes that could cause discomfort (Bregman, 1978). Sound stimuli were delivered to each panellist using a Sennheiser headset (Series HD 518: Sennheiser Electronics GmbH and Co. KG, Wedemark, Germany) connected to a standard PC sound card. The order of stimuli presentation was randomised and counterbalanced using a Latin square design (MacFie, Bratchell, Greenhoff, & Vallis, 1989) to reduce participant and researcher bias. A silent (control) condition without sound was included to act as a reference condition.

Visual stimuli

Photos of the three different café settings corresponding to where the background sounds were recorded were obtained using a Nikon D3000 digital SLR camera (Nikon Inc., Melville, NY, USA). All adjustments of the camera were set to “Automatic”. The camera was mounted on a Bogen-Manfrotto Maxi Repro Stand Lite assembly (Bogen Imaging Inc., Ramsey, N.J., U.S.A.) with the lens looking forward.

Food stimuli

Gelati samples were selected for use in this study as it is a semi-solid food sample, which possess an ideal temporal profile (Chung, Heymann, and Grün, 2003). In addition, chocolate ice cream has been identified as an emotional food sample which evokes stronger emotional response compared to other food samples like bell pepper (Jager et al., 2014).

Dark chocolate (DC), bittersweet chocolate (BC) and milk chocolate (MC) gelato samples were obtained from a local gelati shop. Samples were transported to a sensory laboratory using packed polystyrene boxes, and remained refrigerated (-14°C) until served. Each gelato sample (5.0 ± 0.5g) was placed separately in a 25 ml plastic container coded with a three-digit random number. All samples were tempered for 1 min at room temperature prior to serving. The 1 min increment was determined to be the most appropriate tempering time by observing the condition of the ice cream as a function of time at room temperature.

The serving temperature (−12 ± 2 °C) was strictly monitored to maintain consistency (Bower & Baxter, 2003). Samples were coded with a 3-digit number, randomized, and counter balanced (Macfie et al. 1989). The samples were served under white light. The gelati varied mainly in fat content, which was highest in MC (22%) followed by BC (17%) and DC (10%). In terms of cocoa content, DC contained the most cocoa (24%), followed by BC (15%) and MC (10%). The highest milk content was in MC (15%), followed by BC (8%), while DC did not contain any milk. The MC flavour also had the least cocoa-to-milk ratio and was less bitter than BC.

Temporal measures of pleasantness

Time intensity (TI) measurement is a standardised temporal sensory measure developed in the 1970s (Cliff & Heymann, 1993). TI parameters related to curve size (area under the curve) are correlated with line or category scaled measures, but TI rate (time of increase or decrease) and curve shape parameters (slope of increase or decrease) provide information that is not present in the conventional data (Lundahl, 1992). Hence pleasantness in this study was rated on unstructured graphical scales represented by straight horizontal lines, 100mm long, anchored by descriptors at each end (0 mm = extremely unpleasant; 100 mm = extremely pleasant).

Affective state measurement

Arousal, valence, and dominance were measured using the Self-Assessment Manikin (SAM) described by Bradley and Lang (1994) in order to assess participants' affective responses to the stimuli. Arousal represents the level of *excitement* perceived. Valence represents the *pleasantness* perceived, and the dominance dimension represents the *assertiveness* of the stimulus perceived, that is, its ability to direct attention (Soleymani, Chanel, Kierkels, & Pun, 2008). Nine-point continuous SAM scales for valence, arousal, and dominance were presented to participants (Lang, 1980; Shang, Fu, Dienes, Shao, & Fu, 2013; Suk, 2006). Affective state measures were done prior to the trial for each separate stimulus (audio and audiovisual stimulus without food), and after panellists rated temporal pleasantness of gelati (DC, BC, and

MC) with different eating environment sounds (café, bar, and fast-food restaurant) under audio only or audiovisual condition.

Psychoacoustic analysis

In psychoacoustics, parameters other than sound pressure level can be used to describe a sound. These parameters include tonality, fluctuation strength, roughness and sharpness, all of which co-vary with human responses to sound (Fastl & Zwicker, 2007). Tonality is a measure of the relative content of pure tones in a sound, with noise being an example of a sound low in tonality. Fluctuation strength is a measure of amplitude modulation - that is, cyclic variations in amplitude, and roughness a measure of modulation with lower frequencies (15 Hz to 300 Hz). Sharpness is a measure of the relative content of high frequencies in a signal. In the current study these psychoacoustical parameters were calculated using the National Instruments LabVIEW 2013 software (Austin, TX, U.S.A).

Training

Participants were trained for approximately 10 hours on the basic concept of time intensity measurements (Veldhuizen et al., 2006), definitions of pleasantness, arousal, valence, and dominance, and use of the SAM scale (Bradley & Lang, 2000a; Soleymani et al., 2008; Suk, 2006). Arousal represents the level, or intensity, of the emotion elicited by a stimulus. Valence represents the *pleasantness* perceived, and the dominance dimension represents the *assertiveness* of the stimulus perceived, that is, its ability to direct attention (Soleymani et al., 2008). In addition, a dummy trial using dark chocolate gelato was carried out as a practice trial in order to familiarise participants with the TI method.

Procedure

To begin with, participants were exposed to the food and sound stimuli separately. Participants were asked to rate each stimulus in terms of pleasantness on a 100mm unstructured line scale that was anchored "extremely unpleasant" on the left and "extremely pleasant" on the right. The static pleasantness rating of chocolate gelati was carried out during silence (without any sound stimuli). Prior to temporal pleasantness ratings, participants were also asked to rate the arousal, valence, and dominance of the sound or audiovisual stimulus using the 9-point continuous SAM scale. This was done to observe whether the stimuli differed significantly in terms of valence, arousal, and dominance.

For temporal pleasantness measurements (gelati only), the Time Intensity (TI) method was used (Veldhuizen et al., 2006). Participants were told at the start of each trial to specifically rate their pleasantness of gelati while the sounds were played. Concurrently, participants were instructed to consume the gelati sample as directed by onscreen instructions: "Please place sample in mouth for the first 10 seconds" and "Please swallow sample at the tenth second of the trial". This was specifically done to reduce any individual differences in eating patterns and reduce the variability across participants. Pleasantness was rated for up to 45 seconds. The FIZZ Acquisition system (Biosystemes, France) recorded the ratings twice a second. After evaluating each sound-food pair, participants were given a compulsory 45 seconds break. Participants were asked to rate their affective dimensions (valence, arousal, and dominance) using the 9-point continuous SAM scale after each TI pleasantness measure.

In a second study, the effect of combined audio-visual stimuli on the perception of pleasantness was investigated. The pictures of the three different café settings corresponding to each sound stimulus was presented full-screen as the participants evaluated temporal pleasantness ratings of the chocolate gelati. The Time Intensity (TI) scale was presented as an overlay at the lower part of the picture with a tightly wrapped white background for participants' ease of use. Participants were also asked to rate their affective dimensions using SAM after TI measurement of pleasantness of each gelati sample.

Data analysis

Three separate one-way repeated measures ANOVAs were carried out on the affective responses (i.e., valence, arousal, and dominance) of panellists to the three audio samples. Temporal pleasantness data were analysed by examining the TI curves under different sound and no sound conditions. The extraction of TI parameters was based on the decomposition of the TI curve in three successive phases: an ascending phase, stationary phase, and descending phase respectively (Chung, Heymann, & Grün, 2003). The TI parameters were compared across the three sound and silent (as a control) conditions and gelati samples. Parameter extractions were performed using the FIZZ System

(Biosystemes, France). The measured parameter in this study was the maximum intensity (IMax). Since individual panel members may score peak pleasantness at different times (Overbosch, Van den Enden, & Keur, 1986), IMax was used as a measure of perceived pleasantness in this study, as implemented in other studies (Alves et al., 2008; Harker, Lau, & Gunson, 2003; Veldhuizen et al., 2006).

Repeated measures two-way ANOVA were carried out to test the effect of gelati type (DC, BC, and MC) and sounds (café, fast food restaurant, bar, and control) on the following dependent variables: IMax, valence, arousal, and dominance. For all ANOVAs, the degrees of freedom were adjusted by using the Greenhouse-Geisser correction if the sphericity assumption was violated. If main effects were found ($p < .05$), then *post hoc* comparisons between independent variables were performed using Tukey's HSD (honest significant difference) test. In addition, a repeated measures three-way ANOVA were carried out to test the within-subjects' factors of food, sounds, under either audio or audiovisual conditions in order to investigate the differences in pleasantness and affective dimensions.

Pleasantness curves derived from the time-intensity data were further analysed following the methods described by Dijksterhuis and coworkers (Dijksterhuis & Eilers, 1997; Dijksterhuis, Flipsen, & Punter, 1994). For each food-sound sample pairs, non-centred principal time intensity curves (NPTIC) were determined by Principal Component Analysis (PCA). The evaluations on each separate product (assessed by 45 participants) were used to extract NPTIC's. Differences between NPTIC's for different food-sound pairs were analysed using ANOVA Partial Least Squares Regression (APLSR). The X-matrix consisted of indicator variables (identifier matrix) for experimental design. This comprised a total of of twelve products under four conditions (3 sounds and 1 control condition) for three different gelati flavours (DC, BC, and MC). The Y-matrix consisted of extracted NPTIC's.

Results

Affective ratings of stimuli

The three different auditory contexts (i.e., café, bar, and fast food) were rated independently (i.e., not in the presence of gelati or visual cue) and shown to be significantly different in terms of valence ($F_{(3,311)} = 435.13$, $p < .01$), arousal ($F_{(3,311)} = 220.05$, $p < .01$), and dominance ($F_{(3,311)} = 106.2$, $p < .01$), as seen in Figure 6A. The café sound was rated the most pleasant followed by the fast food restaurant sound, bar sound, and control condition. In terms of arousal and dominance, the control condition was shown to be the least arousing and dominating, followed by the café, fast food and bar sounds in that order.

Audiovisual stimuli (static visual picture with audio) from café, fast food restaurant, and bar settings were likewise rated individually along affective dimensions. Different audiovisual cues (café, bar, and fast food restaurant) were rated independently (without gelati) and were significantly different in terms of valence ($F_{(2,266)} = 195.54$, $p < .01$), arousal ($F_{(2,266)} = 121.54$, $p < .01$), and dominance ($F_{(2,266)} = 76.29$, $p < .01$), as displayed in Figure 6B. The café audiovisual cue was the most pleasant followed by the fast food restaurant and bar audiovisual cues. In terms of arousal and dominance, the café cues were shown to be the least arousing and dominating, followed by the fast food and bar cues.

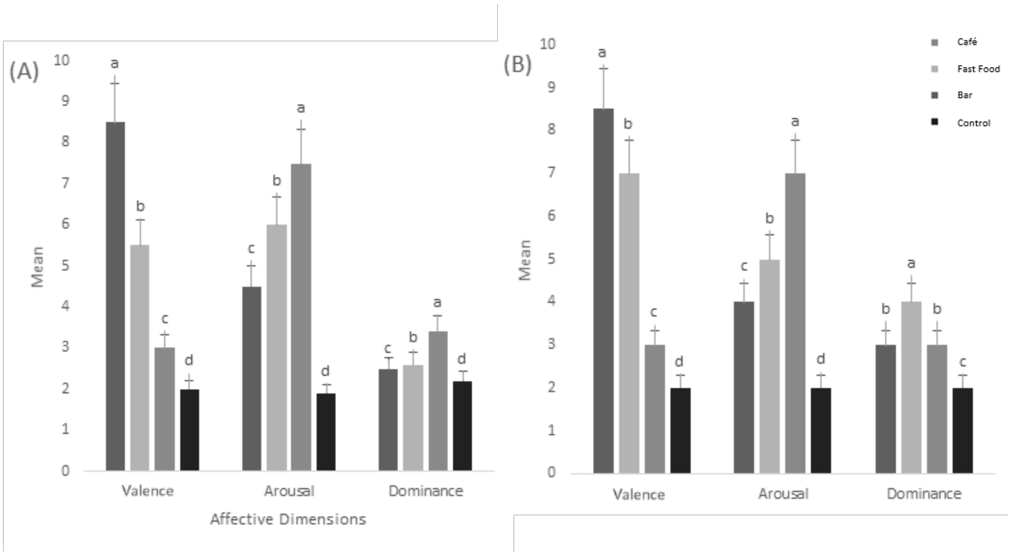

Figure 6. Affective ratings of (A) audio, and (B) audiovisual stimulus in terms of valence, arousal, and dominance for three sound contexts before gelato consumption. [a,b,c,d]: mean affective ratings of sound samples with different letters significantly differ in terms of affect dimensions

Pleasantness ratings of food stimuli

Gelati samples (DC, BC, and MC) were also rated independently (without sound stimuli) in terms of pleasantness. The gelati samples were significantly different in terms of pleasantness ($F_{(2,222)}$ = 1568.18, $p < .01$). MC, with the most fat and milk, and least cocoa, was judged to be the most pleasant followed by BC and DC (Figure 7).

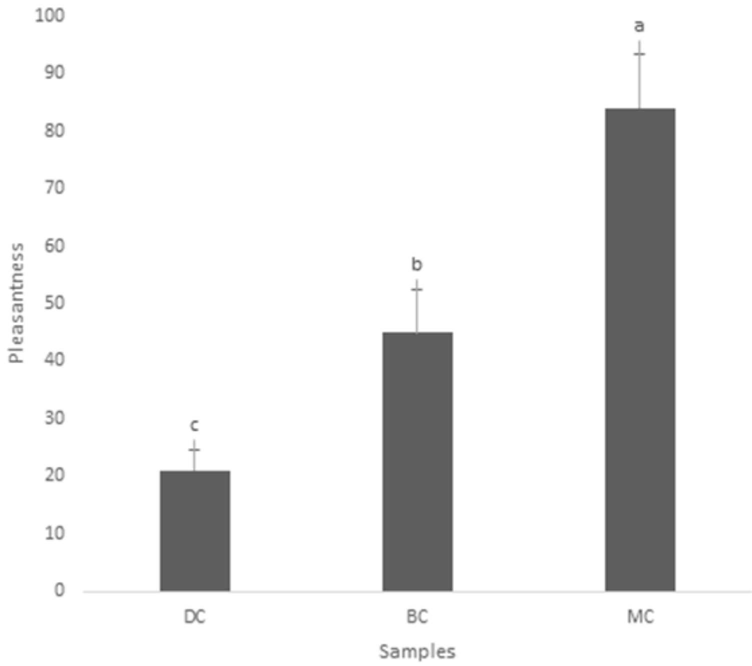

Figure 7. Pleasantness ratings of three chocolate gelati. DC: Dark Chocolate, BC: Bittersweet Chocolate, MC: Milk Chocolate. [a,b,c]: mean pleasantness ratings of food samples with different letter significantly differ in terms of pleasantness.

Psychoacoustic characteristics and perceived quality of sound samples

The café sound had the highest fluctuation strength and lowest loudness value. In contrast, bar sound had the lowest fluctuation strength and roughness, and were the loudest followed by fast food restaurant sound (Table 5).

Table 5. Zwicker's (2007) psychoacoustic parameters of the sound samples

Sample	Loudness (*Sone*)	Sharpness (*acum*)	Fluctuation strength (*vacil*)	Roughness (*asper*)
Café	39.04	3.515	2.47	0.4
Fast food restaurant	45.29	3.407	1.425	0.4
Bar	51.62	4.075	0.711	0.3

Influence of various stimuli on the pleasantness of chocolate gelati

Effect of sound stimuli

Maximum temporal pleasantness rating was represented as maximum pleasantness (IMax) in this study. Sounds of different eating environments were shown to be a significant main factor ($F_{sound\ (3,\ 1023)} = 3849.1$, $p < .01$) influencing pleasantness of the three types of chocolate gelati. In addition, the different gelati types also showed a significant main effect ($F_{gelati\ (2,\ 1023)} = 672.61$, $p < .01$) as to be expected as the gelati varied in pleasantness. Interactions between the two factors (gelati flavour and sound stimuli) for pleasantness (IMax: $F_{gelati*sound\ (6,\ 1023)} = 53.59$, $p < .01$) were significant. Although the decreasing trend across sound environments is common to all three flavours, the relative differences in IMax among the flavours is different from one sound environment to another. For the cafe environment, IMax values of the three flavours are equally spaced, increasing from Dark to Bittersweet to Milk. For fast food restaurant and bar, Dark and Bittersweet have equal IMax values, both lower than Milk. For the control environment, Dark has a lower IMax value than both Bittersweet and Milk, which have similar values in this environment. Figure 8A shows significantly higher maximum pleasantness ratings of the three chocolate gelati with the café sound, followed by fast food restaurant and bar sounds, and the least in control condition. This trend was observed for all three chocolate gelati.

Effect of audiovisual stimuli

Audiovisual stimuli and different flavours of gelati showed significance for maximum temporal pleasantness (IMax) ($F_{\text{audiovisual}\ (3,1023)} = 5675.57$, $p < .01$; $F_{\text{gelati}\ (2,1023)} = 991.77$, $p < .01$). Interactions between the two factors (gelati flavour and audiovisual stimuli) for pleasantness (IMax: $F_{\text{gelati*audiovisual}\ (6,\ 1023)} = 79.02$, $p < .01$) were significant. Figure 8B shows significantly higher maximum pleasantness ratings of all three chocolate gelati with the café sound followed by fast food restaurant, bar, and the control condition. Maximum temporal pleasantness of audio-visual conditions was found to be significantly higher than the audio only condition ($F_{(1,2103)} = 616.73$, $p < .01$).

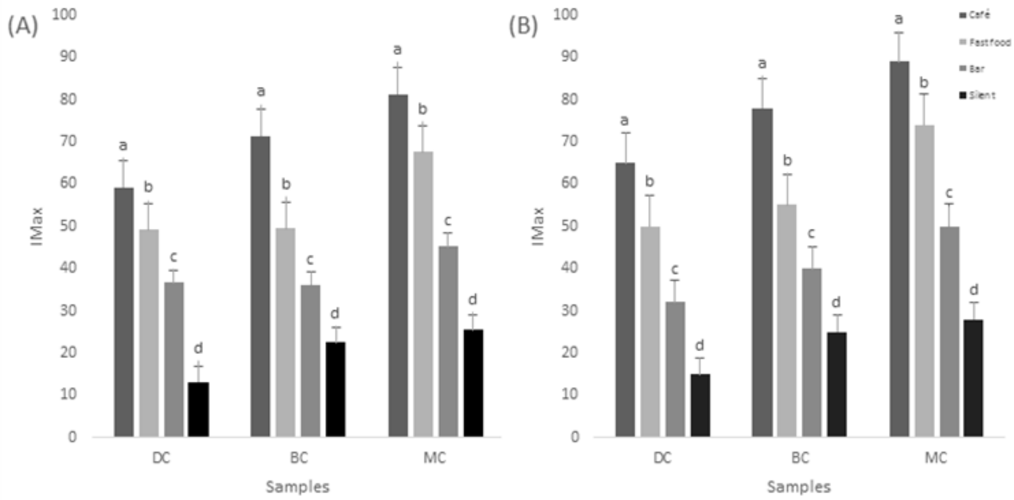

Figure 8. Maximum pleasantness rating of each chocolate gelato in (A) different eating sound environment, and (B) different audio-visual environment. a,b,c,d: mean maximum pleasantness intensity (IMax) of gelati samples significantly differ with different letter

Influence of various stimuli on the affective dimensions of chocolate gelati

Effect of sounds

Playing different sounds while eating showed significant differences in terms of arousal ($F_{sound\ (3,\ 1023)} = 2178.35$, $p < .01$; $F_{gelati\ (2,1023)} = 438.36$, $p < .01$), valence ($F_{sound\ (3,1023)} = 1486.65$, $p < .01$; $F_{gelati\ (2,1023)} = 277.45$, $p < .01$), and dominance ($F_{sound\ (3,1023)} = 221.65$, $p < .01$; $F_{gelati\ (2,1023)} = 114.51$, $p < .01$). Significant interactions between the two factors (gelati flavour and audiovisual stimuli) were also observed for arousal ($F_{gelati*sound\ (6,\ 1023)} = 89.32$, $p < .01$), valence ($F_{gelati*sound\ (6,1023)} = 18.03$, $p < .01$) and dominance ($F_{gelati*sound\ (6,1023)} = 15.09$, $p < .01$) under different sound conditions. Figures 9A, 10A, and 11A illustrate the differences in affective dimensions of gelati samples with different sound conditions. Gelati samples were perceived to be significantly more arousing and dominant when listening to bar sounds, followed by fast food and café sounds. In contrast, all gelati types were perceived to be significantly more pleasant when listening to café sounds, followed by fast food restaurant and bar sounds.

Effect of audiovisual condition

Participants' exposure to audiovisual condition while eating resulted in significant differences in arousal ($F_{audiovisual\ (3,1023)} = 3782.54$, $p < .01$; $F_{gelati\ (2,1023)} = 214.12$, $p < .01$), valence ($F_{audiovisual\ (3,1023)} = 5739.58$, $p < .01$; $F_{gelati\ (2,1023)} = 431.25$, $p < .01$) and dominance ($F_{audiovisual\ (3,1023)} = 1121.95$, $p < .01$; $F_{gelati\ (2,1023)} = 130.63$, $p < .01$). Significant interactions between the two factors (gelati flavour and audiovisual stimuli) were also observed for arousal ($F_{gelati*audiovisual\ (6,1023)} = 54.21$, $p < .01$), valence ($F_{gelati*audiovisual\ (6,1023)} = 93.14$, $p < .01$) and dominance ($F_{gelati*audiovisual\ (6,1023)} = 56.71$, $p < .01$) with the three different audio-visual conditions. As seen in Figure 10B, valence ratings were significantly higher for all three chocolate gelati with the café sound followed by fast food and bar sounds, and then control. The responses of affective dimensions while eating in the two different environments (audio vs. audio-visual stimulus) were also significant for arousal ($F_{(1,2103)} = 209.56$; $p < .01$), valence ($F_{(1,2103)} = 549.25$; $p < .01$) but not in terms of dominance ($F_{(1,2103)} = 0.72$; $p = .485$). Affective ratings perceived under audio-visual conditions were significantly higher compared to audio-only condition except for dominance.

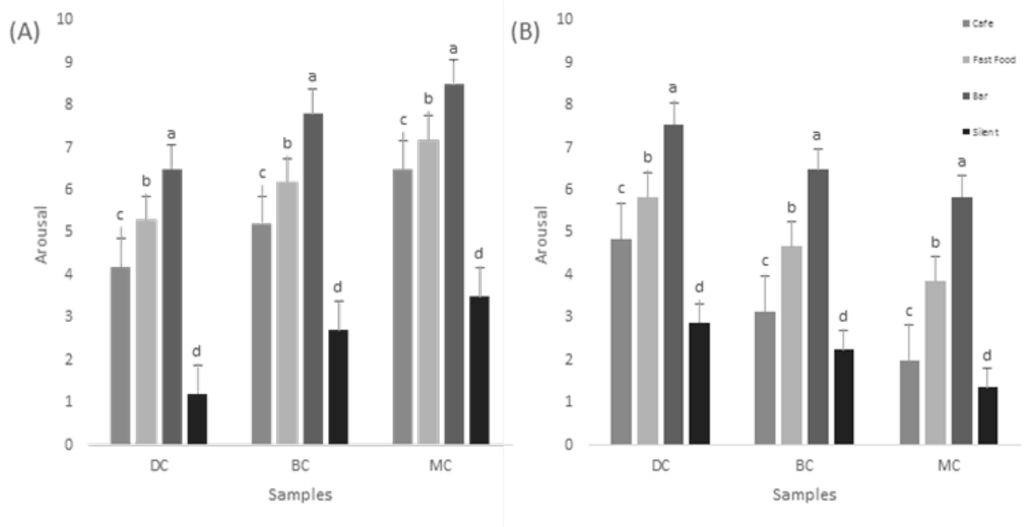

Figure 9. Arousal rating of each chocolate gelato in (A) different eating sound environment, and (B) different audio-visual environment after gelato consumption. [a,b,c,d:] mean arousal rating of gelati samples significantly differ with different letter in terms of the same sample with different stimulus.

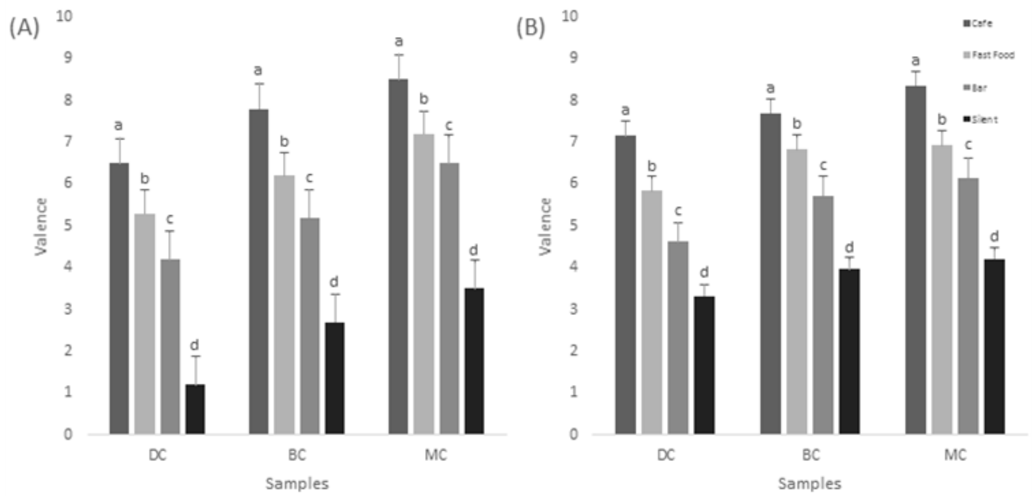

Figure 10. Valence rating of each chocolate gelato in (A) different eating sound environment, and (B) different audio-visual environment after gelato consumption. [a,b,c,d]: mean valence rating of gelati samples significantly differ with different letter in terms of the same sample with different stimulus.

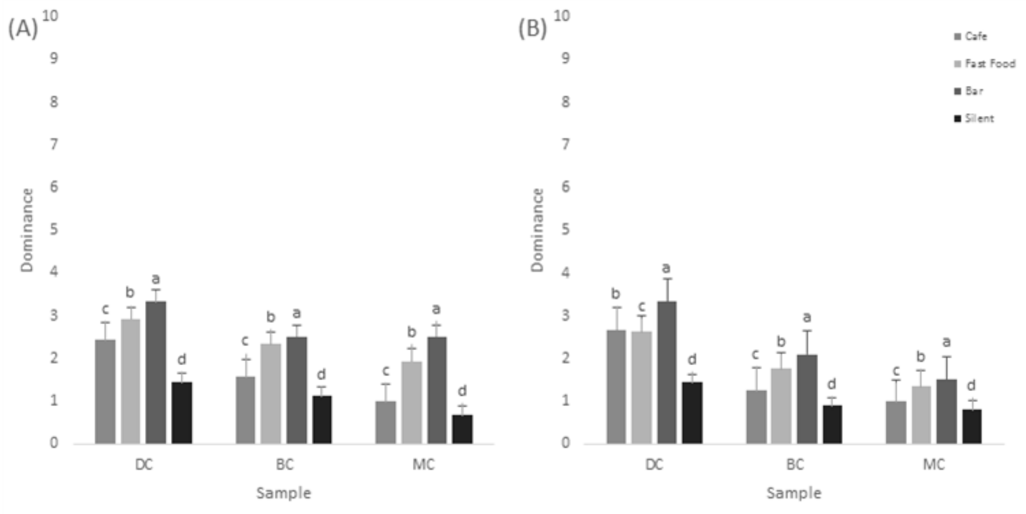

Figure 11. Dominance rating of each chocolate gelato in (A) different eating sound environment, and (B) different audio-visual environment after gelato consumption. [a,b,c,d]: mean valence rating of gelati samples significantly differ with different letter in terms of the same sample with different stimulus.

Multivariate approach on temporal pleasantness data with APLSR

The ANOVA Partial Least Square Regression (APLSR) approach to TI analysis was first published by Frøst, Heymann, Bredie, Dijksterhuis, and Martens (2005) to characterize products according to time points. Non-centered Principal Component Analysis (PCA) scores (NPTIC) were used in this study to derive the “best average” of pleasantness ratings overtime, while accounting for the differences and similarities in individual responses. An APLSR provides validation measures for sample differences based on the NPTIC data, and in the present context provides information on time regions that best separated gelato-sound pairs samples.

The three different types of gelati (MC, BC, and DC) are separated in terms of pleasantness according to the sound conditions they were consumed under demonstrating the order of effect. The effect of the sound condition is larger than gelato flavour. The interaction effect between gelato flavour and sound condition can be noted in the unique patterns displayed under different sound conditions. There are larger differences in pleasantness under the silent condition, as the intragroup distance is largest. In addition, DC and BC were more different than BC and MC samples. In the fast food and café conditions, there are smaller differences in pleasantness overall. DC was again the most different from BC and MC samples. However, in the bar condition, a different trend was observed where MC was least similar to BC and DC samples.

The course of pleasantness (the loadings for T_{start} to T_{end} – Figure 12) shows that that differences are largest in the time-period of increasing intensity of pleasantness (11-16 seconds) and decreasing intensity (25-30 seconds). Between 11-16 seconds (this must be around IMax, as it is right after the ingestion), the gelati consumed under the Café condition had the highest pleasantness intensity, followed by the Fast food condition, and then lower yet similar intensities for silent and bar conditions. However, gelati consumed under the bar condition between 25-30 seconds had the highest intensity of pleasantness, particularly for DC and BC samples. Over this time frame, gelati consumed in the café and fast food conditions were the least pleasant. These patterns were also evident in the plot of average NPTICs for the individual gelati (data not shown) under different eating conditions. Similarly Frøst et al. (2005) reported that the increasing and decreasing intensity regions observed in the APLSR results showed similar patterns with averaged NPTICs.

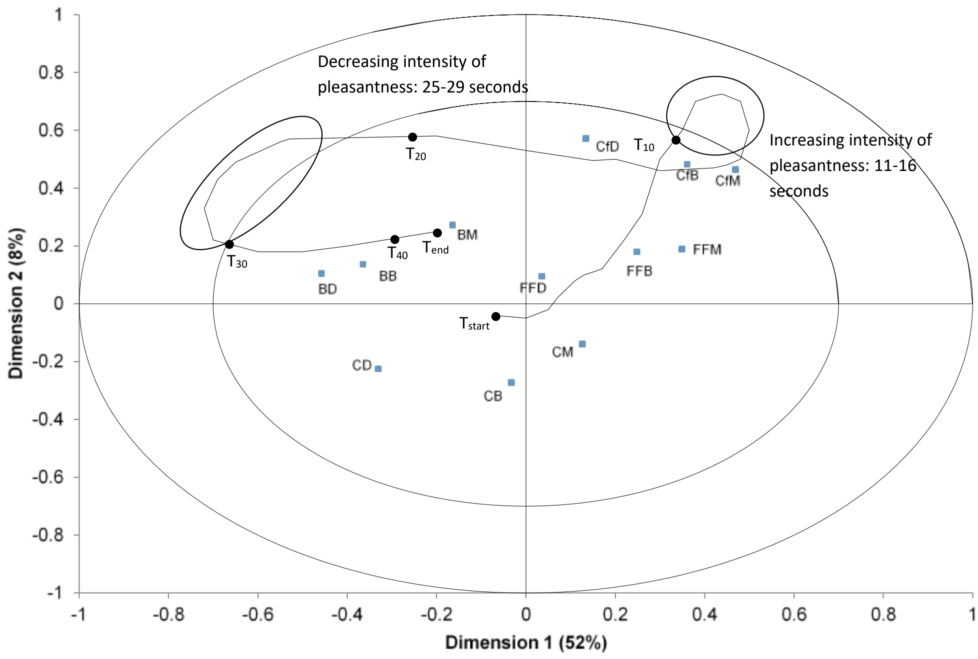

Figure 12. Correlation biplot for APLSR of pleasantness. The inner and outer circles represent 50% and 100% of explained variance. ^{C,B,FF,Cf}: Different letters corresponds to different environmental cues; Control, bar, fast food restaurant, and café sounds respectively. ^{D,B,M}: Different letters corresponds to different gelati flavour; Dark, Bittersweet, and Milk chocolate flavour respectively. T_{Start}/T_{End}/$T_{10,20,30,40}$: Starting/end point/time points (10, 20, 30, 40 seconds) in time progression.

Discussion

Different environmental eating sounds elicits different affective ratings

Under audio and audiovisual conditions, the café sound was rated the most valent, least arousing and dominating, followed by fast food restaurant, and bar sounds. Similarly, Bradley and Lang (2000a) reported that when playing a sound stimulus, affective responses such as valence and arousal varied across sound types.

In terms of gelati, MC with the highest fat and milk content, was rated the most pleasant, followed by BC, and DC. J.-X. Guinard, Zoumas-Morse, Mori, Panyam, and Kilara (1996) reported that acceptance was positively related to vanilla, creamy, fatty and milky characteristics of ice cream. The gelati used in this study varied in fat content, with the highest in MC followed by BC and DC. DC, which had the least fat content was judged to be significantly less pleasant than MC and BC. Reduction in fat and sugar in ice cream has been reported to cause a decrease in acceptance (Cadena, Cruz, Faria, & Bolini, 2012), textural liking (Aime, Arntfield, Malcolmson, & Ryland, 2001), melt rate (El-Nagar, Clowes, Tudorică, Kuri, & Brennan, 2002), and flavour release (Hyvönen et al., 2003).

Fastl & Zwicker (2007), suggest that people's psychoacoustical evaluations of sounds determines their subjective responses (i.e., pleasantness and arousal). According to Zwicker's psychoacoustics and sensory pleasantness model, listeners experience sounds as less pleasant when sounds are perceived as s*harper*, *rougher*, or *louder*. Given the high ratings of roughness, sharpness, and loudness, our participants may be judging the acoustic contexts as unpleasant. The high fluctuation value for the café is likely a result of its relative quietness preventing the masking of low amplitude sounds from refrigeration and air conditioning units. In contrast, bar sounds that had the highest loudness value, and were lowest in fluctuation strength and roughness compared to fast food restaurant and café sounds. Thus in line with Fastl and Zwicker's theory (2007), we conclude that café sound were the most pleasant followed by fast food restaurant, and bar sounds.

From the findings above, differences in pleasantness were evident for separate audio, audiovisual, and gelati types used in this study. It was important for individual stimuli (sound, audiovisual, and food stimulus) to vary in affective dimensions in order to adapt the Mehrabian Russell's (M-R) model of Stimulus-Organism-Response (S-O-R) to explain the differences in pleasantness of chocolate gelati in terms of the affective response of the environmental cues. We predict that the cues that varied in affective terms would influence the pleasantness of gelati samples.

Sounds and audiovisual cues can influence the pleasantness of gelati

Sounds and audiovisual cues of different eating environments were shown to be significant factors influencing pleasantness of the three types of chocolate gelati. Stapel et al. (1998) reported that different atmospheric cues elicited significant differences in consumer perceptions of the environment. In their study, "Elegant" hotel cues were rated significantly higher in terms of arousal and valence than "casual" fast-food cues. Cherulnik (1991) reported that photographs of different restaurant facades influenced common cognitive representations. For example, pictures of expensive restaurants were characterized by adjectives such as delicious, elegant, comfortable, and relaxing. Elaborate designs were also associated more with expensive restaurants than the "sandwich shops" that evoked more simple design associations.

Maximum temporal pleasantness ratings of gelati were higher under the audiovisual condition compared to the audio only condition. This may be due to the provision of more relevant sensory information in the audiovisual stimuli condition where participants were provided not only the sound but also the static pictures (visual stimuli) of the eating environment (Imram, 1999). In a recent study, Bangcuyo et al. (2015) developed an immersive environment depicting a virtual coffeehouse, complete with congruent visual, auditory and olfactory cues, and compared the liking of five coffee types consumed to a testing environment in which contextual information was absent. They found that coffee samples consumed in the immersive setting were more acceptable. This further illustrates the influence of environmental sensory information on food acceptance and liking.

Affective dimensions of chocolate gelati can explain changes in pleasantness

This is the first study to show differences in affective dimensions (i.e., arousal and valence) during eating while being exposed to different environmental cues. Gelati is perceived as more pleasant when sounds are present. Bradley and Lang (2000a) suggested that cues with high valence ratings and high arousal ratings would be associated with appetitive (i.e., approach) responses, while sounds with lower valence and high arousal ratings would be associated with defensive (i.e., avoidance) responses. Based on the affective ratings obtained in this study, it can be argued that the café sound would induce mostly appetitive emotions (i.e., high pleasantness and low arousal), while the fast food sound with its midscale affective ratings, would induce emotions that were neither appetitive nor defensive (i.e., mid valence, mid arousal). The bar sound on the other hand had the lowest valence ratings (i.e., was unpleasant) and could be argued to induce the most defensive-focused emotions (high unpleasantness, high arousal). Finally, similar to the fast food condition, the silent (control) condition was also non-appetitive or non-defensive (low valence, low arousal). In relation to the consumption of the gelati, it could be speculated that in inducing different emotional responses, different sonic environments can affect food perception.

This study also showed that *dominance*, based on the pleasure-arousal-dominance (PAD) model proposed by Russell and Mehrabian (1977) could be a very important indicator in understanding consumers' affective response as implemented by Jang and Namkung (2009). A review by Yani-de-Soriano and Foxall (2006) reported that dominance in retail research has been mainly absent in published studies purporting to adapt the PAD model. A study by Medvedev et al. (2015) reported a significant increase in skin conductance level while listening to a dominating sound compared to their baseline. Psychoacoustical research suggests that changes in skin conductance is an indicator of attention (Frith & Allen, 1983), and thus it may have been that the bar sounds in this study are the most distractive, and cafe sounds the least.

It was found that pleasantness of audio-visual conditions was significantly higher compared to the audio-only condition (Section 3.4.2, where $F_{(1,2103)} = 616.73$, $p < .01$). This could be due to the enhancing effect of the visual stimulus when accompanied by an auditory stimulus (Stein et al., 1996). Baumgartner et al. (2006) demonstrated the effect of emotional responses between matched and unmatched audio, visual and audiovisual stimuli. Participants showed higher emotional responses to the combined conditions (audiovisual condition), followed by the picture conditions, and lowest in the sound conditions. The differences in their emotional responses were explained in terms of activation levels, which was highest in the combined conditions (audiovisual).

In our study, under audio and audiovisual conditions, café sound elicited positive emotions that resulted in significantly higher pleasantness rating of gelati compared to other sound conditions (fast food restaurant and bar sounds). The Mehrabian and Russell (M-R) model reported that individual responses to stimuli are related to emotional states represented by a combination of two affective dimensions: pleasure, and arousal (Russell & Mehrabian, 1977). In this study, sounds that have high valence ratings tended to increase the pleasantness of the gelati. This further confirms the contribution of affective dimensions such as valence and arousal on auditory and visual stimulus towards food perception.

APLSR differentiated between gelati consumed under different environmental cues

Changes in temporal pleasantness of gelati samples consumed under different audio and audiovisual cues of eating environments were observed using multivariate techniques. By plotting a biplot (Figure 7), we were able to observe the changes in time points and loadings of each environmental cue and sample pair. On the first factor, the bar sounds that were negatively valent were negatively loaded. In contrast, fast food and cafe sounds that were positively valent were positively loaded. Study done by Meiselman et al. (2000) had shown lower significant differences in sensory quality of food consumed in a dining hall compared to training restaurant. The authors suggested that the differences were attributed to contextual effect of the environment itself. Similarly, in our study where gelati samples played with valent sound (café) was found to be significantly pleasant compared to the least valent sound (bar).

Gelati samples consumed in the control condition, separated by factor 2, were perceived to be the least pleasant. A study undertaken by Pellegrino et al. (2015) reported that only 3.7% of participants in their study preferred eating in silence, while most preferred eating with music, in front of the TV, or while having a conversation. It can be reasonably argued that an individual's need for sound and their dislike of silence is a learnt behaviour (Fell, 2012).

Time points for Factors 1 and 2 from the vector loadings of APLSR model further highlighted time regions that best separated products in terms of pleasantness as carried out by Frøst et al. (2005). Cafe sounds, which were the most pleasant and least dominant were perceived earlier (11-16 seconds). The bar sounds, which were the least pleasant and most dominant were perceived later in the time region (25-29 seconds). This can be explained by the differences in attentional level of the sounds which affected distraction in this study. Nowlis et al. (2004) demonstrated the negative effect of delayed (waiting) time as a factor of distraction when consuming chocolate, which was considered a pleasant stimulus. Enjoyment of chocolate in their study increased after a delayed period. They suggested that the wait or distraction may have aroused consumers' anticipation level. This may help explain the delayed pleasantness of chocolate gelati while listening to bar sound in our study.

Limitations

This study omitted the sound pressure factor, which is a part of the ambience in the different environments by standardizing the sound pressure to comfortable listening sound. In our pilot test, the sound sample when presented as it is, resulted in the bar sounds being perceived to be too loud to the point of discomfort.

Considering ecological validity, the acoustic environments across the conditions are in reality highly variable. On a week night a bar may be very quiet, and during a lunch time rush a café can be incredibly noisy. The data in this study represents the point on the amplitude continuum where the different environments might be considered to have equivalent noise levels. We acknowledge, however, that on average these noise levels will be reasonably displaced from one another. In addition, by focusing on comparison of different soundscapes at an equal sound intensity, we need to explicitly state that our results offer a conservative estimate of the impacts of the sonic environment on perception, and had we used the mean levels then the differences would have been likely more pronounced. Therefore, we recommend that future studies would also include the impact of sound intensity as an experimental factor while investigating the effects of auditory cues on food perception. This study also explored the influence of soundscapes or so-called environmental noises without considering the presence of music in the background – which is commonly played in eating environments. Music can evoke emotions and play a major role in eating behaviour. Hence, further studies should explore the affective influence of music on temporal sensory perception. This is carried out in chapter 5 of this thesis.

Conclusion

In summary, our findings demonstrated the influence of audio and audio-visual cues on pleasantness ratings of chocolate gelati. Pleasant audio and audiovisual stimuli can enhance food pleasantness. A more immersive environment that includes a combined audio-visual stimulus can further enhance pleasantness and affective ratings, thereby providing more ecological validity compared to a laboratory environment. Further study using various audio-visual stimuli from different eating environments and/or different food stimuli is needed to confirm the current findings. In addition, temporal perception of taste and flavour can also be investigated to further explain the changes in pleasantness over time. In this study, we have explored the influence of sounds and the underlying effects of vision and sound, and their impact on food pleasantness judgments. This may create a clear emphasis on the importance, influence, and its potential use of immersive technologies through which visual and auditory cues can potentially influence the gastric experience.

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Conflict of Interest Statement

Gianpaolo Grazioli owns Giapo Ice Cream. His contribution to the study was to provide the gelato sample and some insights of the experimental design. There have been no involvements that might raise the question of bias in the work reported or in the conclusions, implications, or opinions stated.

Chapter 5. Listening to music can influence hedonic and sensory perceptions of gelati

Kevin Kantono [a], Nazimah Hamid [a*], Daniel Shepherd [b], Michelle JY Yoo [a], Gianpaolo Grazioli [c] and B.Thomas Carr[d]

[a] School of Applied Sciences, Auckland University of Technology, Private Bag 92006, Auckland 1142, New Zealand

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

[c] Giapo Ice Cream and Research Kitchen, 279-281 Queen St., Auckland 1010, New Zealand

[d] Carr Consulting, 1215 Washington Ave. Suite 203, Wilmette, IL 60091, USA

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

Highlights

- Music can influence the taste of chocolate gelati
- Liked music elicits positive emotions, which is correlated with sweetness
- Music also influenced hedonic responses to chocolate gelati

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Abstract

The dominant taste sensations of three different types of chocolate gelati (milk chocolate, dark chocolate, and bittersweet chocolate) were determined using forty five trained panellists exposed to a silent reference condition and three music samples differing in hedonic ratings. The temporal dominance of sensations (TDS) method was used to measure temporal taste perceptions. The emotional states of panellists were measured after each gelati-music pairing using a scale specifically developed for this study. The TDS difference curves showed significant differences between gelati samples and music conditions ($p<0.05$). Sweetness was perceived more dominant when neutral and liked music were played, while bitterness was more dominant for disliked music. A joint Canonical Variate Analysis (CVA) further explained the variability in sensory and emotion data. The first and second dimensions explained 78% of the variance, with the first dimension separating liked and disliked music and the second dimension separating liked music and silence. Gelati samples consumed while listening to liked and neutral music had positive scores, and were separated from those consumed under the disliked music condition along the first dimension. Liked music and disliked music were further correlated with positive and negative emotions respectively. Findings indicate that listening to music influenced the hedonic and sensory impressions of the gelati.

Keywords: music, gelato, emotion, taste, temporal dominance of sensation, congruency

Introduction

How people experience food is largely determined by the gustatory and olfactory senses (Ramírez, Martínez, Fernández, Corti Bielsa, & Farina, 2010). However, beyond the dominance of taste and smell there are other sensory systems contributing to food perception, including the trigeminal, visual, tactile, and auditory systems. This multisensory nature of food perception is an on-going area of enquiry, and while it has yet to be determined how diverse sensory dimensions integrate (Sester et al., 2013), studies on cross-modal sensory integration suggest that one sensory modality can enhance the response of another if both are active concurrently (Sagiv & Ward, 2006).

When considering cross-modal sensory interactions in the food sciences, the most often overlooked modality is audition (Spence & Shankar, 2010), which is unfortunate, as for most people food is rarely consumed in silence. Indeed, the sonic background in which we consume our food has been shown to influence our food choices (Stroebele & De Castro, 2004), rate of consumption, identification, and hedonic experiences (Spence & Shankar, 2010). However, while a number of cross-modal interactions have been reported in the literature, including taste and odour; flavour and irritation, and; flavour and colour (H.T. Lawless & Heymann, 1999), comparatively less is known about the effect of the auditory modality on food perception. Of the few studies reported in the literature, interactions between pitch of musical instrument and five basic tastes of food names (Crisinel & Spence, 2009), flavours of chocolate milk with varying fat content (Crisinel & Spence, 2011), and pleasantness ratings of chocolate (Crisinel & Spence, 2012) have been demonstrated. More recently, the interaction between music genre and both flavour and overall food impressions have been reported (Fiegel et al., 2014). In Fiegel's study, participants consumed emotional (milk chocolate) or non-emotional (bell peppers) food while listening to four music genres (classical, jazz, hip-hop, and rock). The milk chocolate sample was significantly higher for overall impression when participants listened to jazz music compared to hip-hop music. The authors considered several mechanisms when explaining their findings. These included mechanisms that involved direct interaction between sensory cortices (Schroeder & Foxe, 2005; Wesson & Wilson, 2011), a cross-modal contrast (Van Wassenhove et al., 2008), attentional processes (Grabenhorst & Rolls, 2008), and association effects due to implicit links between sounds and tastes (Crisinel & Spence, 2009). However, participants in the study did not listen to music varying along dislike-like continuum, and emotion data was not collected to explore the differences in emotional responses elicited by the different music genres. These overlooked aspects will be investigated in the current study.

Liking and congruency of sounds have been associated with food liking and pleasantness. A study by Woods et al. (2011) showed a positive correlation between sound liking and food liking. Various savoury and sweet stimuli from soft and crunchy food categories were all rated lower in terms of both liking and taste intensity in loud compared to quiet sound conditions. Seo and Hummel (2011) further reported that auditory stimuli that were congruent with odour would increase the pleasantness ratings of the odour stimulus. For example, the sound of a Christmas carol increased the pleasantness of cinnamon odour ratings. The authors suggested the valence of the sound could influence the valence of the odour, regardless of the valence liking of the odour itself. The more the participants liked the sound, the more pleasant the odour was rated.

Music has been known to influence mood and emotional states. .Blood and Zatorre (2001) reported that playing pleasant music increased cerebral blood flow in the brain regions associated with reward, motivation, and emotion. In contrast, playing unpleasant music increased paralimbic activity, a brain region associated with unpleasant emotions. It has been observed that mood states, in turn, can influence taste perception. Heath et al. (2006) reported that participants who were given systemic monoamines to induce positive mood had lower sucrose thresholds and higher bitterness thresholds. Similarly, Platte et al. (2013) showed that participants in a positive mood state rated sucrose solutions sweeter while perceiving quinine sulphate solution to be less bitter, than when in a negative mood state. In this study, we aimed to explore whether the mood mechanism hypothesised by Woods et al., (2011) could explain the perceptual changes in flavour of food evoked by the auditory stimuli.

The Temporal Dominance of Sensations (TDS) method measures the pattern of dominant sensations elicited by a stimulus over a certain time period, specifically the identification of dominant sensations and the rating of their intensity (Pineau et al., 2009). A recent study by Jager et al. (2014) utilized TDS to measure the temporal dominance of taste and flavour attributes elicited by chocolate, as well as the dominant emotions. They found an association between the sensory and emotional attributes that characterized flavoured and plain dark chocolates. Flavour attributes were dominant and positive/active emotions were reported present with flavoured dark chocolates. On the other hand, textural and taste attributes were dominant in the plain dark chocolates, which were associated with more negative/non-energetic emotions. This was also supported by Fiegel et al. (2014) suggesting that the changes in taste perceptions were attributed to emotions, which were easily transferrable to the ratings of emotional food (chocolate) compared to non-emotional food (bell peppers).

Our study builds upon the work of Fiegel et al. (2014), who investigated the static relationship between music and both flavour and overall impression of food. In this study we employ TDS to measure temporal changes in taste perceptions while chocolate gelati is consumed in the presence of music that varied in liking. Temporal measures of gustatory perception were used as they provide a better description of the continuous effect of music on flavour and taste perception. This is important as music itself is a temporal stimulus (Tenney & Polansky, 1980). In addition, emotional states were measured at the end of each TDS trial for each music and food pairing. The central aim of this study was to determine whether changes in taste of chocolate gelati could be modulated by music and, if so, explained using emotion as a mechanism. The playing of music serves as an experimental manipulation of mood in this study, and takes into account individual variance in music preference.

Materials and method

Ethics Statement

The Auckland University of Technology Ethics Committee approved the study (AUTEC 12/79), and panellists gave written informed consent prior to the commencement of the study.

Panellists

Forty-five panellists (20 males, 25 females) between 21 and 41 years of age participated in the study. They were recruited online through an advertisement posted on social networking services (i.e., Facebook and Instagram), and were rewarded for their participation. None of the panellists were smokers, and none reported hearing loss, eating disorders, or other health problems associated with food.

Panel Training

Panel training was carried out over three sessions totalling 10 hours. Panellists were informed that they would be listening to music while consuming chocolate gelati. In the first training session, panellists familiarized themselves with the measurement of taste sensations using the TDS procedure, and were introduced to the concept and measurement of dominance. Panellists were trained to familiarize themselves with ‘dominance’ attributes, defined as the attribute associated to the sensation catching the attention at a given time, and to understand that dominance might switch when a new sensation arrives (Labbe et al., 2009; Pineau et al., 2009). In addition, panellists were required to rate the intensity of a selected dominant attribute, for example, *bitterness*. They were also instructed on how to use an unstructured line scale, anchored “none” and “extreme” (Pineau et al., 2009). A dummy TDS trial was carried out in the second training session using samples of bittersweet chocolate gelato that was both *sweet* and *bitter* tasting. In the third session, panellists undertook simulated TDS trials on samples of bittersweet gelato while listening to 45 seconds of music, allowing them to become familiar with the computer interface and the TDS methodology. In this final session, panellists were also acquainted with food-related emotional attributes scales, and were given a both a definition and an example of events associated with the emotion (Desmet & Schifferstein, 2008). For example, *happiness* was described as a feeling of pleasure and contentment, and the event examples included: “*I'm happy after my late lunch, I was very hungry*”, “*I’m happy that I’ve eaten healthy food*” and “*I'm very happy with the quality of this food*”.

Music Selection and Song Preference Rating

The 14 musical genres (Blues, Folk, Classical, Jazz, Alternative, Heavy metal, Rock, Country, Religious, Pop, Funk, Hip-Hop, Soul, and Electronica) described by Rentfrow and Gosling (2003) were used to guide song selection and subsequent measures of music preference. Song selection per musical genre was obtained from iTunes, which utilizes the Gracenote CDDB database to determine each song's genre. The Gracenote CDDB database registers the song genre that is chosen by the author of the song. Subsequently, a focus group consisting of eight people (21 to 35 years old), who were regular music listeners (at least 2 hours per day), agreed on one song that best represented each genre, and were asked to provide keywords to describe its musical characteristics (Table 6).

The songs were downloaded from iTunes (Apple Inc., 2012) in m4a format, with an average bit-rate of 256 kbps to achieve high quality sound. The audio samples were then modified using Adobe Audition CS6 (Adobe Systems Inc., U.S.) batch processes. The root mean square amplitudes of the audio samples were standardized to an internal reference to achieve equivalent sound pressure levels across the songs, and then scaled to 70 dB SPL using a Brüel and Kjær measuring amplifier. This is considered a reasonable volume to present songs while avoiding amplitudes that could cause discomfort or hearing loss. The audio samples were then played using a standard PC soundcard through a Sennheiser headset (Series HD 518: Sennheiser Electronics GmbH and Co. KG).

Before starting the experiment, all forty-five panellists listened to the first minute of each genre's representative song (re: Table 6) and then made a preference rating using an unstructured 100 mm line scale anchored with "extremely disliked" on the left and "extremely liked" on the right. After rating all 14 genres, the highest liking score given by each panellist was taken to be their most liked piece of music. The lowest liking score was considered their disliked music, while the song with a rating closest to 50 was classed as the neutrally liked music. It is important to note that for this study individual variation in music preference was taken into account (see Table 7). Hence the music set (liked, disliked, and neutrally liked music) played for each individual as they consumed gelati likely varied across panellists.

Table 6. Musical genres and songs used in this study.

Genres	Artist	Song	Musical Description
Classical	Alfred Brendel	Für Elise	Piano, clearer texture, elegance
Folk	Mumford and Sons	Sigh No More	Transformative, uplifting, urbane
Alternative	Alanis Morissette	Narcissus	Inventive, inspiring, sensual
Rock	Gotye Featuring Kimbra	Somebody That I Used To Know	Atmospheric, cluttering, mannered
Country	Lee Brice	A Woman Like You	Heart-warming, guitar, country
Pop	Glad You Came	The Wanted	Strong beat, invigorating, generic
Soul	Kanye West	All of the Lights	Rattling, raw, ghetto
Blues	Ray Charles	I Got A Woman	Gospel, radio like, emotional
Jazz	Louis Armstrong	La Vie En Rose	Swings, calm, slow
Heavy Metal	AC/DC	Thunder Struck	Loud, sharp, metal
Religious	Larnelle Harris	Dream On	Religious, calming, slow
Funk	James Brown	Living in America	Groovy, 1980s-like
Hip Hop	Black Eyed Peas	Can’t Get Enough	Rapping, slow beats, rhythmic
Electronica	Jack Back ft David Guetta	Wild One Two	Electronic, dance, high beat

Gelati Preparation and Presentation

Three different chocolate gelati, dark, bittersweet, and milk chocolate (hereon DC, BC, and MC, respectively), were used as bitter, sweet and bitter and sweet (transitional) stimuli, respectively. The gelati varied mainly in fat content, which was the highest in MC (22%), followed by BC (17%) and DC (10%). In terms of cocoa content, DC (24%) contained the most cocoa, followed by BC (15%) and MC (10%). The highest milk content was in MC (15%), followed by BC (8%), and DC did not contain any milk. This design of having bitter, transitional and sweet samples follows Crisinel and Spence (2012), who studied the influence of musical notes on pleasantness ratings of three flavoured chocolates (dark, marzipan filled – transitional, and milk chocolate).

A scoop of each gelato sample (5.0 ± 0.8 g) was placed individually into a sealed white plastic container (45 mm diameter) coded with a three-digit random number. Samples were stored in a commercial-grade freezer (Fisher and Paykel, NZ) at -18 °C for at least 24 h prior to testing. All samples were tempered for one minute at room temperature prior to serving, determined by observing the condition of the gelati as a function of time at room temperature. The serving temperature (−12 ± 2 °C) was strictly monitored to maintain consistency (Bower & Baxter, 2003). Sample presentation was randomized, and counterbalanced across panellists.

TDS Procedure

Prior to data collection, a second pilot study was undertaken to determine the optimum listening time of the music samples using the time intensity method. Panellists evaluated 14 different musical genres and a silent condition (i.e., a reference condition) while consuming five grams of BC gelato, and rated the pleasantness of the gelato sample using an unstructured hedonic line scale anchored 'extremely unpleasant' and 'extremely pleasant' on the left and right poles respectively. Pilot data indicated that songs played for 45 seconds from the beginning was a sufficient duration to rate the pleasantness and to measure temporal taste perceptions of the gelato. After 45 seconds the TI curve showed a lag stationary phase for pleasantness.

TDS measurements were obtained for the three different types of gelati under four sound conditions: liked, disliked, and neutrally liked music conditions, and a silent condition (i.e., the reference condition). Each sensory booth contained a computer screen that presented instructions on how to consume the gelato sample over time. TDS ratings of all samples were obtained using a 100 mm unstructured line scale, with sweetness, bitterness, saltiness, sourness, and umami being displayed in order from the top of the computer screen. Panellists were asked to continuously report any changes in taste perception of the gelato sample during the 45-second period of listening to the music; in other words, from the first bite to swallowing and, if present, to aftertaste sensations. Specifically, panellists select a new dominant attribute whenever they perceive a change in dominant sensations. "Dominant" has been defined as the sensation that either captures one's attention, is perceptually the most striking, or is the sensation that 'pops out' at a given time even though it is not necessarily the most intense sensation (Labbe et al., 2009; Pineau et al., 2009). As soon as the panellist clicked the unstructured line scale on the computer screen, the music (except for the silent condition) played, and the panellist was prompted to place the gelato sample into their mouth. On the 25-second mark, the panellist was instructed to swallow the gelato sample. The action of clicking on the line scale that appeared on the computer screen activated the software to record TDS ratings every second for up to 45 seconds. All ratings were recorded using FIZZ sensory data acquisition software (FIZZ Network v2.46b, Biosystemes). Detailed instructions were given to minimize variation in consumption behaviour. A compulsory 45-second break in between samples was provided to allow panellists to drink and rinse their mouth with filtered water. The use computers of responding and isolated booths served to reduce social desirability related bias in this study (Booth-Kewley, Larson, & Miyoshi, 2007).

Data collection started when panellists clicked on a start button on the screen to begin the evaluation. During an evaluation, the panellist selected the dominant attribute and rated it on an unstructured line scale. If the dominant perception changed, the panellist changed to the on-screen scale that corresponded to the new taste sensation and rated its intensity. The panellist was free to choose the same attribute several times or, conversely, to not select an attribute as ever being dominant. Additionally, a duration parameter was computed as the time elapsing between the elicitation of the given attribute and the following elicitation. This means an attribute is considered dominant until another attribute is scored as such.

Upon evaluating all three gelato samples consumed during a silent period or in the presence of music, the computer screen faded out to indicate the end of the experimental session. The presentation orders of the four sound conditions and the three gelati flavours were randomized across panellists. In addition, after a TDS trial for each gelati sample and music (or silence) pairing, emotion, and pleasantness ratings were elicited. The experiment was repeated after a week had elapsed. All trials were carried out on weekdays between 12:00 and 2:00 pm.

Emotion and Pleasantness Measurements

A preliminary study using a focus groups consisting of twelve students (4 males, 8 females) between 21 and 34 years of age was done in order to develop a relevant food-music emotion scale so as to capture related food-music emotions that might be evoked during a trial. In this study, eighty adjectives relating to emotions were compiled from the food-related literature (Ng et al., 2013) and music literature (Zentner, Grandjean, & Scherer, 2008). Emotional terms without reference to food or music were selected from the Profile of Mood States (McNair, Lorr, & Droppleman, 1971), Multiple Affect Adjective Check List Revised (Lubin & Zuckerman, 1999), Positive and Negative Affect Scale (Watson, Clark, & Tellegen, 1988), and the Geneva Affect Label Coder (Scherer, 2005). Out of the initial 80 emotion terms, ten terms were extracted using the three selection steps described by Chrea et al. (2009) and Ferdenzi et al. (2011). Panellists evaluated the terms on a continuous scale for its ability to describe the affective states elicited by the gelato, music, and both gelato and music. However, panellists were not provided any gelato and (or) music samples during this step. Panellists were allowed to modify the emotional terms if necessary. panellists were asked to define the affective terms that they had agreed on and to give an example of an event that may trigger the agreed affective terms. Only the relevant and well-understood terms were kept. Nine of the emotional terms identified from the circumplex model (Posner et al., 2005) were used, comprising 3 positive and high arousal terms (*Amusement, Happiness, and Enjoyment*), 3 negative and high arousal terms (*Anger, Contempt, and Disgust*), 2 positive and low arousal terms (*Love and Surprise*), and an unclassified emotion term (*Satisfaction*). The developed scale utilized an unstructured line scale labelled from "not at all" (0) to "extremely" (100).

Data analysis

Panel dominance curves

Panel dominance curves for TDS were generated using the FIZZ software (v. 2.46b). The determination of chance and dominance levels on panel curves were carried out using the methods developed by Pineau et al. (2009) and Lenfant et al. (2009). Chance level is defined as the dominance rate that an attribute would obtain by chance. Its value, P_0, is equal to $1/p$, where p is the number of attributes being monitored. Significance level is the minimum value this proportion should equal in order to be considered significantly higher than P_0. This was calculated using the confidence interval of a binomial proportion based on a normal approximation.

Temporal dominance curves depict the proportion of panellists who selected the attribute as dominant at a given time. Consistent with Lenfant et al. (2009), the dominance rate for each product (i.e., the proportion of panellists who scored each attribute) is computed at each point of time. High proportions indicate a consensus among panellists to agree that a specific attribute is dominant at a given time. These proportions are plotted against time for the different attributes in a Panel Dominance curve.

Standardized Time

The TDS time period in this study is presented as standardized time as this will lead to a better understanding of the perceptual process and greater consensus across the whole panel. Each panellist's time data was standardised to a score between 0 and 100, 0 representing when they clicked the line scale to start and 100 when they clicked stop or when recording stopped automatically. Spline-based smoothing was applied on each curve (Ng et al., 2012).

Emotion and pleasantness

To explore whether gelati and music pairs were significantly related to the emotional states of the panellists (the dependent variable), and pleasantness ratings of gelati, a full factorial ANOVA with gelati (3 levels) and music (4 levels) as within groups factors was performed, with *post hoc* Tukey's analysis applied if significance was observed.

Differences between genre likings

A Chi-square test was carried out on the frequency counts of panellists' least/neutral/most liked music genre to determine whether there were differences in genre liking. The Chi-square statistic was deemed significant if the p-value was less than 0.05.

Canonical Variate Analysis of Duration and Frequency of Sensations

Using the duration of dominance as the dependent variable, Canonical Variate Analysis (CVA) was conducted to evaluate the differences between gelati based on each and both emotional and sensory attributes (Jager et al., 2014). Three CVAs were carried out on sensory, emotional, and both sensory and emotional data. In addition, Hotelling-Lawley Multivariate Analysis of Variance (MANOVA) tests sought evidence of significant differences between each product loadings (α=.05). CVA was used in this study as it can maximize the distances between products, while minimizing residual variability (Monrozier & Danzart, 2001).

Results and discussion

Selection of Liked, Neutral and Disliked Genres

There was no significant association between music genre and liking categories across panellists (Table 7), indicating a diversity of music preferences among respondents, and reinforcing the argument that individual preferences to music need to be accounted for in research of this type. Fiegel et al. (2014) investigated the effect of music genre without accounting for music preference. Without taking the liking of each music genre into account their data were skewed, perhaps explaining why they failed to observe statistical significance for flavour intensity and pleasantness, and texture impression, in their data.

Table 7. Chi square analysis results for panellists' frequency for selection of liked, neutral, and disliked music genres.

Genre	**Liked**	**Neutral**	**Disliked**
Classical	0	4	1
Folk	1	1	6
Alternative	4	2	2
Rock	4	2	4
Country	2	4	5
Pop	2	5	3
Soul	7	2	1
Blues	2	1	6
Jazz	3	4	1
Heavy Metal	3	5	3
Religious	8	4	1
Funk	5	4	5
Hip Hop	2	4	2
Electronica	2	3	5
p-value	*0.06*	*0.87*	*0.24*

Food and Music Emotion Scale

Table 8 shows that gelato consumption elicited emotions varying in intensities depending on the music condition. Listening to disliked music elicited significantly greater negative emotions compared to neutral or liked music. Listening to liked music, on the other hand, significantly increased positive emotions. Using brain imaging techniques, Blood and Zatorre (2001) reported that listening to pleasurable (liked) music elicited intense pleasurable experiences described as "shivers-down-the-spine" or "chills". They found that as pleasurable sensations increased, cerebral blood flow increased in brain regions involved with reward and motivation. In contrast, playing unpleasant music showed increased activity in paralimbic brain regions, which correlated with unpleasant emotions. Thus in the current study it is feasible that music differing in valence induced different emotional responses, which subsequently influenced gelati ratings.

Nine of the ten emotional terms chosen by the panellists have been reported in the circumplex model (Posner et al., 2005). The circumplex model separates emotions in two dimensions, valence (unpleasant-pleasant) and arousal (low-high activation). 3 positive and high arousal terms (*Amusement, Happiness, and Enjoyment*), 3 negative and high arousal terms (*Anger, Contempt, and Disgust*), 2 positive and low arousal terms (*Love and Surprise*), and an unclassified emotion term (*Satisfaction*) were used in this study. All 10 emotional terms were relevant to and were also described in the positive and negative emotions list of food experience described by (Desmet & Schifferstein, 2008) . The emotion scale was subjected to Cronbach Alpha analysis and was found to be reliable in capturing emotions during eating.

Table 8. Intensity ratings for emotions and pleasantness evoked by both music and gelati type after the TDS trials. ^{a,b,c,d} mean values of emotion ratings with different superscripts within the same row (different music samples with same gelato flavour) differ significantly ($p < .05$). ^{x,y,z} mean values of emotion ratings with different superscripts within the same column (different gelato flavour with same music samples) differ significantly ($p < .05$).

Parameters	Gelati	Music			
		Disliked	Neutral	Liked	Silent
Disappointment	Dark	44.2^{ax}	32.1^{bx}	28.8^{cx}	9.6^{dx}
	Bittersweet	33.1^{ay}	25.9^{by}	16.7^{cy}	5.1^{dy}
	Milk	25.6^{az}	15.1^{bz}	10.5^{cz}	2.6^{dz}
Disgust	Dark	46.2^{ax}	27.2^{bx}	5.1^{dx}	12.1^{cx}
	Bittersweet	24.8^{ay}	11.7^{by}	4.3^{dx}	8.1^{cy}
	Milk	11.5^{az}	8.1^{bz}	2.1^{cy}	2.7^{cz}
Contempt	Dark	48.2^{ax}	34.5^{bx}	15.5^{cx}	10.7^{dx}
	Bittersweet	41.9^{ax}	20.5^{by}	10.3^{cy}	5.1^{dy}
	Milk	33.2^{ay}	17.7^{bz}	8.7^{cz}	2.3^{dz}
Amusement	Dark	10.4^{ax}	22.4^{bx}	35.1^{cx}	10.2^{ax}
	Bittersweet	17.1^{ay}	22.5^{bx}	35.4^{cx}	20.5^{bz}
	Milk	33.3^{bz}	45.1^{dy}	48.2^{cy}	15.5^{ay}
Happiness	Dark	4.6^{ax}	17.7^{bx}	32.9^{cx}	27.1^{dx}
	Bittersweet	25.1^{ay}	27.6^{ay}	40^{by}	25.7^{ax}
	Milk	30.2^{bz}	38.5^{cz}	52.1^{dz}	25.2^{ax}
Enjoyment	Dark	6.4^{ax}	24.7^{bx}	32.1^{cx}	26.8^{bx}
	Bittersweet	35.1^{ay}	38.7^{by}	56.2^{cy}	32.8^{by}
	Milk	42.2^{az}	53.9^{bz}	63.7^{cz}	52.4^{bz}
Love	Dark	12.3^{ax}	28.3^{bx}	35.6^{cx}	10.7^{dx}
	Bittersweet	32.7^{ay}	48.1^{by}	55.1^{cy}	33.1^{dy}
	Milk	35.1^{az}	58.8^{bz}	65.2^{cz}	45.2^{dz}
Surprise	Dark	55.1^{ax}	9.2^{cy}	14.8^{by}	6.1^{cy}
	Bittersweet	17.2^{ay}	14.8^{bx}	17.3^{ax}	9.2^{cx}
	Milk	17.5^{ay}	10.7^{cz}	14.2^{by}	7.2^{dy}
Satisfaction	Dark	12.2^{cx}	22.4^{bx}	35.6^{ax}	5.1^{dx}
	Bittersweet	21.2^{cy}	38.6^{by}	41.2^{ay}	7.3^{dy}
	Milk	31.2^{cz}	48.2^{bz}	51.1^{az}	9.2^{dz}
Pleasantness	Dark	20.5^{cx}	14.9^{dx}	25.6^{ax}	22.7^{bx}
	Bittersweet	20.1^{dx}	27.9^{cy}	55.4^{ay}	28.3^{bx}
	Milk	20.8^{cy}	56.6^{bz}	67.5^{az}	25.8^{dx}

Pleasantness

There was no significant differences in mean pleasantness scores across the three gelato samples when consumed in silence. Comparatively, gelato samples were significantly different in mean pleasantness across all three music conditions. Pleasantness ratings for gelati were significantly higher for liked music, followed by neutral and disliked music. This indicated that music was likely modulating the pleasantness of the gelati samples. The hedonic tone of auditory stimuli has been reported to influence hedonic ratings of subsequently or simultaneously administered chemosensory stimuli (Seo & Hummel, 2011; Woods et al., 2011). Hedonic judgments of music in our study appear to influence the pleasantness of the gelato samples. This could explain why Fiegel et al. (2014) only found significance in overall impression of food between jazz, hip-hop, and rock but not in terms of flavour intensity, flavour pleasantness, and texture impression, as they had only selected four different music genres (classical, jazz, hip-hop, and rock) without taking into account individual difference in the liking of their music samples.

The overall increase in pleasantness perceptions in this study while listening to liked music can also be explained by the induction of mood (e.g: valence) when listening to music. Here the pleasantness of the music influences the pleasantness of the gelati, regardless of how pleasant the gelati was. Positive associations have also been found between the hedonic ratings of both background sounds and food liking (Woods et al., 2011) and odour pleasantness (Seo & Hummel, 2011). Other studies have reported that listening to liked music can induce positive moods in shopping patrons (Alpert, Alpert, & Maltz, 2005), and clinical patients (Särkämö et al., 2008).

Temporal dominance of sensations

Panel dominance curves

Figures 13 - 15 show smoothed TDS curves using the spline equation for all samples. In our study, with the use of trained panellists, the chance level was found to be 0.20, corresponding to a dominance rate of 20%. Therefore, taste attributes below 20% in our study were not considered dominant. The significance level was calculated with respect to the chance level, and a total of 90 evaluations were performed (45 panellists that participated in duplicate trials). A significance level of 0.28 was derived, corresponding to a dominance rate of 28%. TDS panel dominance curves afford identification of both dominance rate and time of evaluated attributes. Only *sweetness* and *bitterness* were dominant taste attributes in our study. As *saltiness*, *sourness*, and *umami* all failed to reach sufficient chance and significance levels they will not be discussed further.

The attributes selected in this study investigated the changes in taste of chocolate gelati. Implicit association between names of food stuff that has sour, bitter, salty, and sweet taste to pitch has been investigated (Crisinel, 2010; Crisinel & Spence, 2009). High pitched sound was associated with names of food having a sour taste (Crisinel & Spence, 2009) and sweet taste (Crisinel & Spence, 2010b), while low pitch sound was associated with the names of food stuff having a bitter (Crisinel & Spence, 2010b) and salty taste (Crisinel & Spence, 2009). However, no food was consumed in their study. In contrast, Woods et al. (2010) used real various food sample (sweet and savoury foods), had showed that loud white noises dampens taste perceptions particularly in sweetness and saltiness. In addition, Crisinel and Spence (2012) had also found that the bitterness of consumed chocolates increases while listening to low pitch musical instrument tone and sweetness of their chocolates increases while listening to high pitch musical instrument tone. Hence, this study will be the first to explore the temporal taste perception while listening to music as a temporal stimulus as compared to single pitch or sounds.

Only sweetness and bitterness were the only dominant attributes in this study. This can be explained as the chocolate gelati in this study varied with different levels of fat, milk, and cocoa. TDS method was selected in this study as it provides a better description of the continuous effect of music on taste perception. This is, important as music itself is a temporal stimulus (Tenney & Polansky, 1980). The information on intensity obtained from our TDS study was not very useful as duration and dominance rate had provide useful interpretation in TDS. Nicolas Pineau et al. (2012) reported that intensity has been generally recorded in TDS studies mostly for historical reasons, as the first TDS software was based on an evolution of a conventional profiling module. But intensity rating is not recommended because it mixes up two different cognitive processes: the selection of a dominant attribute (qualitative task) and intensity scoring (quantitative task). They made a solid recommendation of using buttons rather than intensity scales for TDS procedures. In addition Dinnella et al. (2013) found that running TDS with and without intensity ratings showed no significance differences in terms of sensory characteristics their coffee samples.

Silent Condition

Gelati types BC (Figure 14) and MC (Figure 15) were significantly sweeter at the onset of mastication (0 – 30% and 0 – 35% standardized time respectively) and then became significantly bitter with time (30% – 88% and 35% – 100% standardized time respectively). Only BC became significantly sweeter after 82% standardized time (Figure 14). DC was the only sample that was significantly bitter and less sweet compared to BC and MC (Figure 13).

It is not possible to compare our findings to previously published studies using TDS and chocolate gelati, as to our best knowledge the existent TDS studies on chocolate gelati or ice cream focus on textural properties rather than taste (Varela, Pintor, & Fiszman, 2014). Only Jager et al. (2014) have investigated taste, flavour, texture perception and emotions of plain and flavoured chocolate using the TDS method. The DC TDS profile in our study is similar to their 85% cocoa chocolate with the dominant attributes of bitterness from 25% of the evaluation period (standardized time) onwards. They attributed this profile to induction of negative emotions, which will be further considered in the CVA section of this discussion. Additionally, the 70% cocoa chocolate from Jager et al. (2014) showed higher dominance rates for sweetness, similar to our MC sample.

Disliked music

For disliked music, the DC gelato was significantly bitter from the onset until the end of the mastication period (0-100% standardized time) (Figure 14), BC was significantly more bitter at the onset of mastication (0 – 45% standardized time) and then became both significantly sweet and bitter (42% – 100% and 72% – 100% standardized time) (Figure 15). In contrast, MC was significantly sweeter at the onset of mastication (0% – 60% standardized time) and then became bitter (55% – 100% standardized time) (Fig. 15). In comparison to the silent condition, listening to disliked music evoked in higher dominance rate of bitterness in DC, shifts bitterness perception in an earlier time period for BC, and evoked a higher dominance rate for bitterness in MC.

Platte et al. (2013) reported that healthy participants exposed to negative mood-inducing video clips rated quinine sulphate to be more bitter than when exposed to a positive video clip. The video clip was used to induce mood, and it is possible that in our study music could have also evoked different mood states. It would also seem that the lowered ratings for disliked music might be due to increased arousal by the negative valence of disliked music, as postulated by Gomez and Danuser (2004) and Bradley and Lang (2000a). Thus, the changes in taste perception in our study may potentially be explained by the induction of a negative mood state when listening to disliked music.

Neutral and Liked music

With neutral music, sweetness of the DC sample was dominant from 40% standardized time until the end of the trial (Figure 13). For the MC sample, sweetness was dominant from the beginning of the trial until the end of the trial. However, in the case of BC, sweetness was dominant when listening to neutral music up to 70% standardized time. Macht and Mueller (2007) examined the immediate effects of eating a piece of chocolate and drinking water on negative, positive, and neutral mood states induced by film clips. Their results showed that mood increased while eating chocolate after watching a neutral film compared to a baseline condition (i.e., no chocolate). Hence the changes in the temporal taste perception of chocolate gelati since listening to neutral music (similar to liked music) might be due to elevations in mood or elicitation of positive emotions.

When listening to liked music, DC and BC had similar panel dominance curves compared to MC. When MC was paired with liked music, sweetness was dominant from the beginning of the trial towards the end, without any perception of bitterness. DC was perceived to be dominantly sweet after 45% of the standardized time, and BC was significantly sweeter when listening to liked music from the onset of mastication period until 60% standardized time. Liked music has been shown to enhance sweetness perception in this study. Platte et al. (2013) reported that participants induced into positive mind states gave higher sweetness ratings in sucrose and lower bitterness ratings in quinine solutions compared to when a negative mood was induced. Here, the final hedonic judgment of the gelati is not fully influenced by the hedonic valence of the music but may also be influenced by the hedonic tone of the gelati itself. For example, MC was rated the most pleasant gelato (Table 8) when paired with the most liked music sample, and this may encourage a congruency effect, which enhances desirable sensory taste attributes (in this case sweetness). This is similar to the findings of Macht et al. (2002), who reported that after viewing a joyful mood-inducing film, there was not only a higher tendency to eat more chocolate, but the chocolate also tasted more pleasant and more “stimulating” than eating it after watching a sad movie. In addition, Macht and Mueller (2007) reported that eating chocolate after watching a positive mood-inducing film significantly elevated mood, as compared to drinking water. Hence, we may conclude that the increase in sweetness in chocolate gelati might be due to an elevation of mood, which can be explained by emotion mechanisms (Platte et al., 2013). Pertinently, positive mood states associated with liked music can heighten arousal levels, increasing sensitivity and lowering taste thresholds; thereby amplifying taste perceptions (Heath et al., 2006).

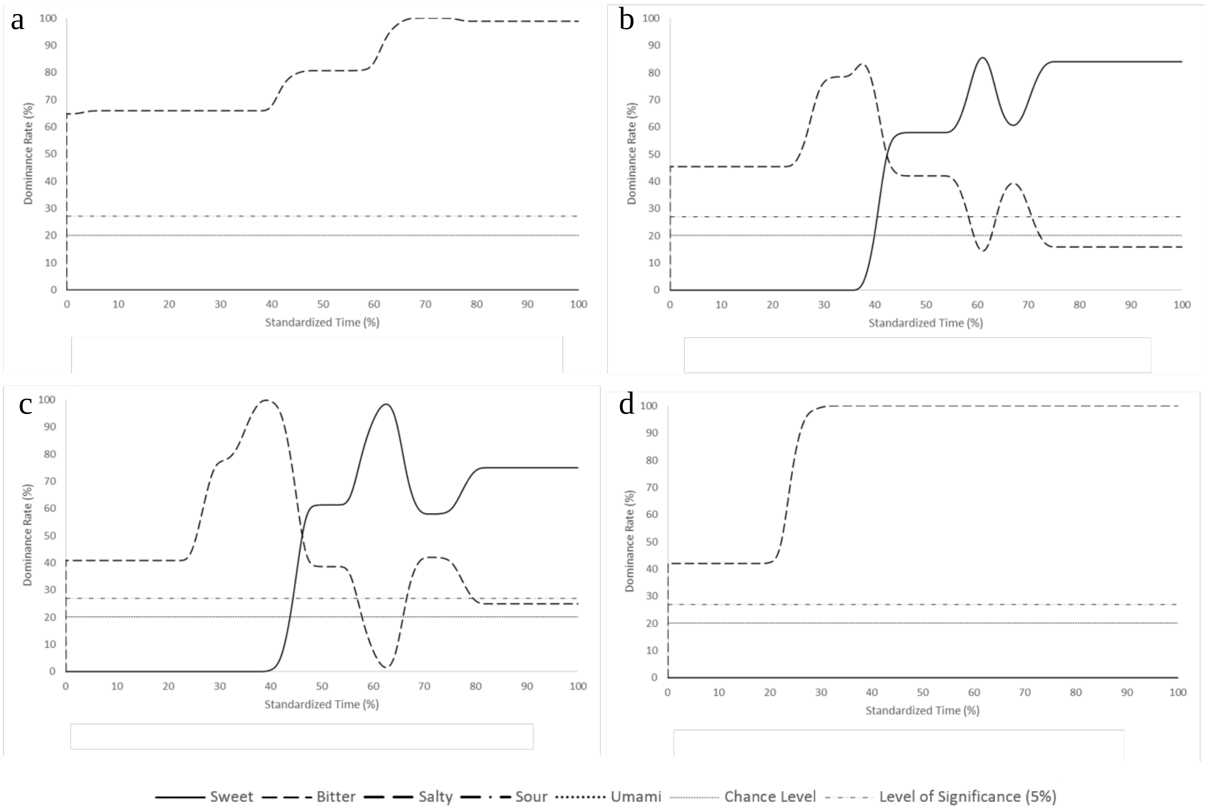

Figure 13. Panel dominance curves for each dark chocolate gelato and music pairs: a) disliked music, b) neutral music, c) liked music, and d) silent

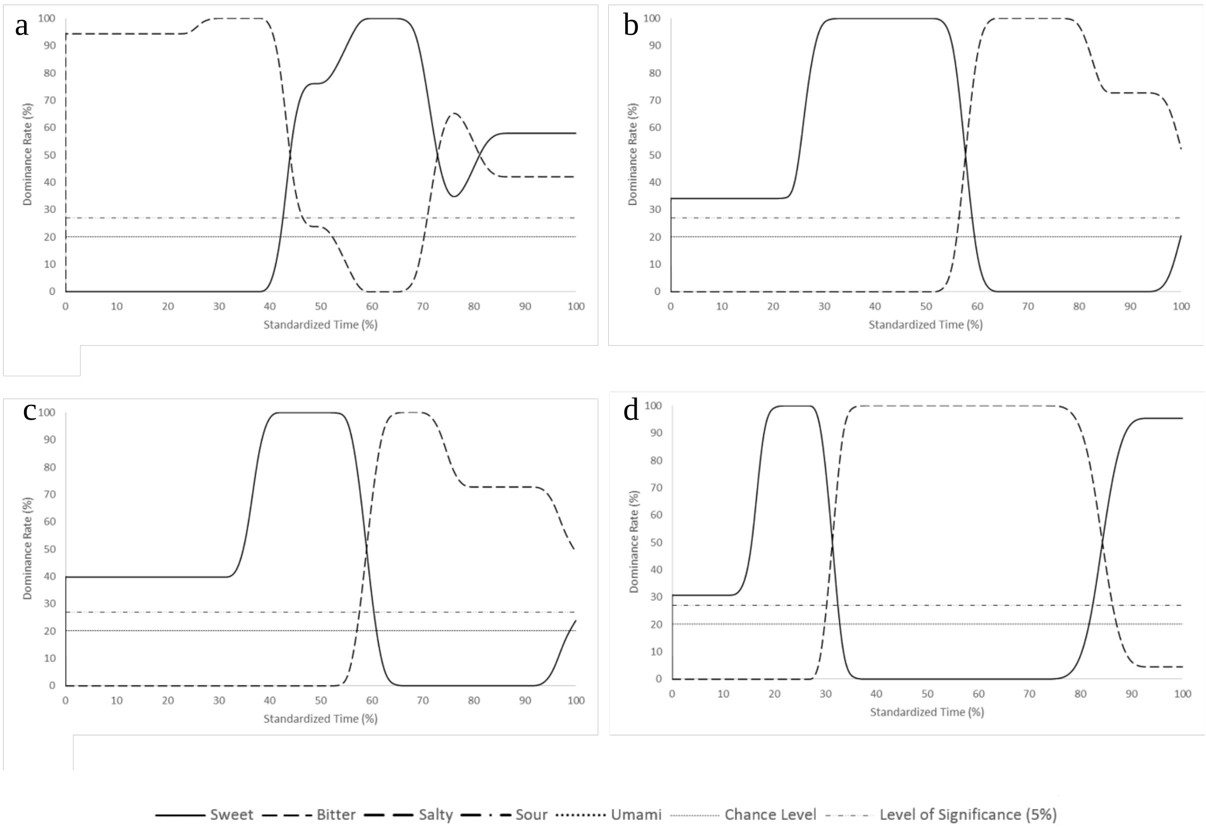

Figure 14. Panel dominance curves for each bittersweet chocolate gelato and music pairs: a) disliked music, b) neutral music, c) liked music, and d) silent

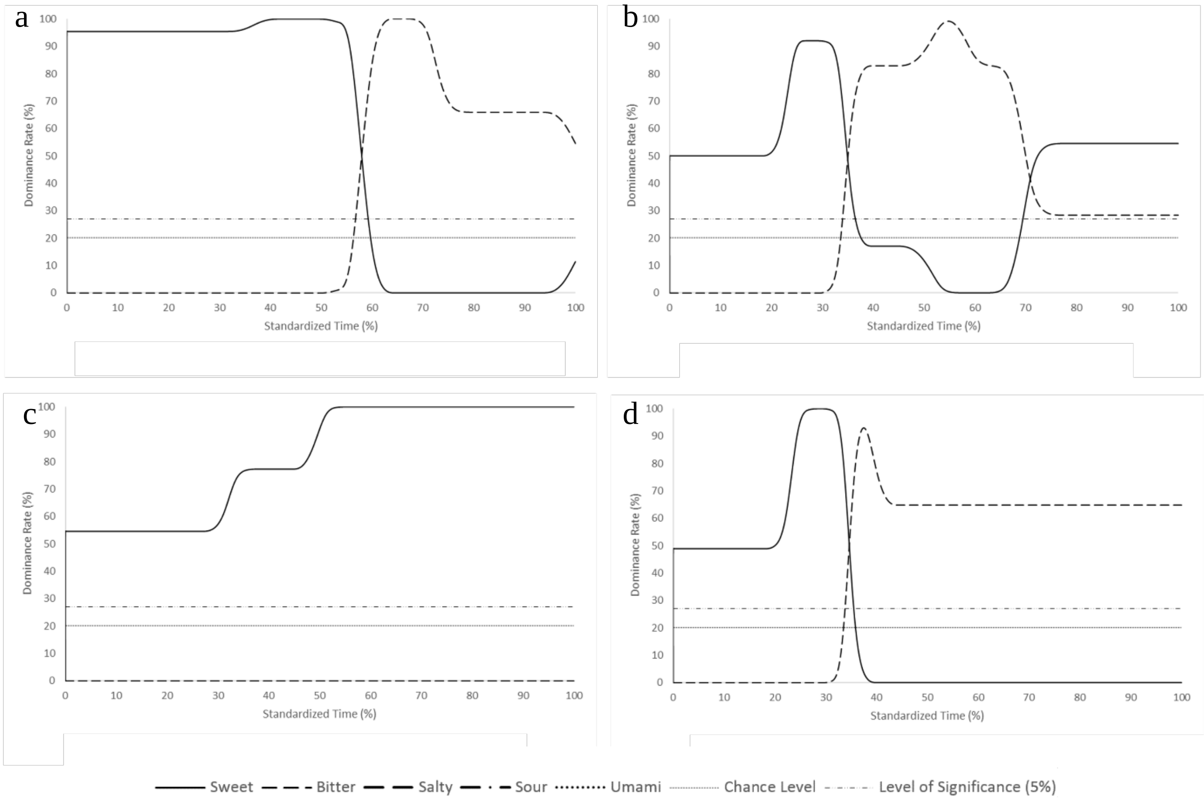

Figure 15. Panel dominance curves for each milk chocolate gelato and music pairs: a) disliked music, b) neutral music, c) liked music, and d) silent

Canonical Variate Analysis

For the sensory and emotional data, separate Canonical Variate Analyses (CVA) were carried out on the duration of dominance per attribute (Fig. 4 and 5). Sample discrimination was explained by the first two canonical variates, which were higher for sensory data (92.2%), and lower for emotional data (78.26%). A pair of MANOVAs were significant for both sensory ($F_{(33, 2423)}$ = 17715.76, p<0.001) and emotional ($F_{(99, 4949)}$ = 85.21, p=<0.001) data.

Figure 16 shows the CVA plot of sensory attributes. The 90%-confidence ellipses indicate that the means of the music-gelati pairs differed significantly. Dimension 1 explains 81.19% of the variance, separating the neutral and liked music-gelati pairs from disliked music-gelati pairs. Dimension 2 (11.01%) further differentiates the gelato samples consumed under the silent (control) condition and the other music conditions. All samples were perceived *sweet* under the liked music condition. Similarly, BC and MC gelati were perceived *sweet* for the neutral music condition. However, for disliked music, all gelati samples were perceived *bitter*. Possible mechanisms that may contribute to changes in taste perception while listening to music include hedonic tone matching and heightened music-elicited emotional arousal. Hedonic tone matching of audio stimuli may have altered the overall pleasantness ratings of the gelati samples. A study carried out by Fiegel et al. (2014) suggested that lower flavour and overall impression ratings for hip-hop music compared to the jazz music may be explained by the hedonic likings of the music itself. However, the authors did not take into account the participants' hedonic liking for the music played, which perhaps explains why most of their flavour intensity, pleasantness, and texture impression results failed to reach statistical significance.

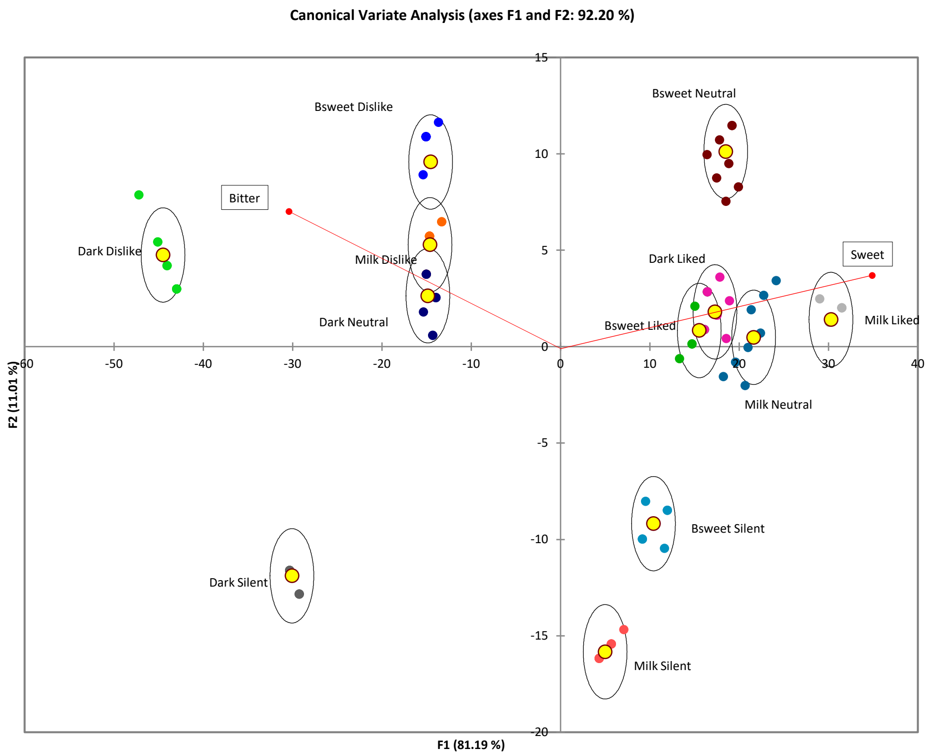

Figure 16. Canonical Variate Analysis Biplot of dominance durations of sensations. Hotteling-Lawley MANOVA test showed significant product differences ($F_{(33,2423)}$ = 17715.76; $p < 0.05$) based on sensory attributes. Each point represents data from a single observer.

Figure 17 shows the CVA plot of the emotional attributes. Dimension 1 (explaining 52.92% of the variability across gelati) distinguishes between the emotional attributes associated with disliked music compared to liked and neutral music conditions. Emotions associated with the disliked music condition were *disgust*, *contempt*, and *disappointment*. BC and MC samples consumed under liked and neutral music conditions evoked *satisfaction*, *enjoyment*, *amusement*, and *happiness* emotions. Dimension 2 (25.35%) further distinguished between gelati consumed under the silent and music conditions. Logeswaran and Bhattacharya (2009) demonstrated that playing happy or sad music increased happiness or sadness ratings, indicating a direct coupling between music and emotional state. Interestingly, when considering neutral music, MC elicited more positive emotions compared to dark and bittersweet chocolate gelati. In our study MC was judged to be the most pleasant sample compared to BC and MC (re: Table 8). As the most pleasant, MC will likely elicit more positive emotions compared to BC and DC. In this study, different hedonic responses to the music likely influence the panellists' emotional state. We also need to take into account that chocolate gelato is an emotional food stimulus. Sweet and fatty foods such as chocolate are considered to be emotional foods, whereas less sweet foods, fruits and vegetables are non-emotional foods (Konttinen, Männistö, Sarlio-Lähteenkorva, Silventoinen, & Haukkala, 2010). A study by Fiegel et al. (2014) reported significant changes in pleasantness with chocolate but no significant changes on bell peppers while listening to different music genres. The authors suggested that changes in taste perceptions were attributed to emotions elicited by background music, which were easily transferrable to the ratings of emotional food (chocolate) compared to non-emotional food (bell peppers). The trends we report here then, may not hold for all food types.

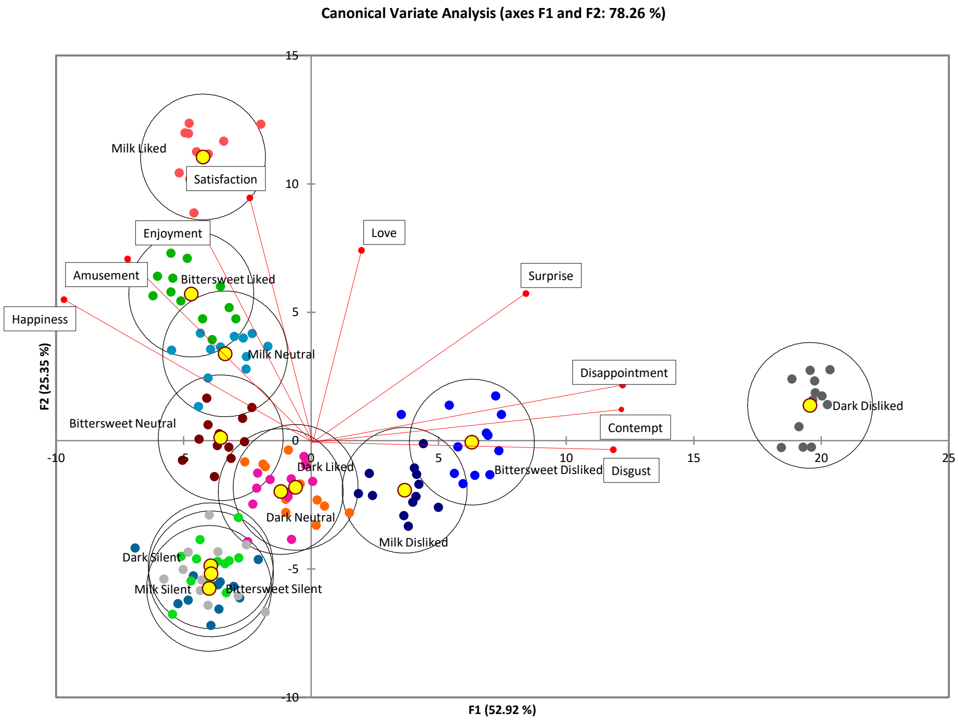

Figure 17. Canonical Variate Analysis Biplot of dominance durations of sensations. Hotteling-Lawley MANOVA test showed significant product differences ($F_{(99,4949)}$ = 85.21; p < 0.05) based on emotion attributes

Figure 18 shows a joint CVA plot for sensory and emotional attributes on the duration of dominance per attribute. This joint map accounts for about 90% of the total variability across gelati. In the first dimension, accounting for 81.77% of the variance, disliked music conditions were separated from liked and neutral music conditions. The second dimension, (11.5%), further separated the silent and music conditions. Liked music was associated with positive emotions and *sweetness*, while disliked music was associated with negative emotions and *bitterness*. Hence, we propose that the emotions associated with music likely influenced the sensory perceptions of gelati samples in this study. Music has been known to modulate mood state of an individual, where positive emotion can be elicited while listening to liked music, and negative emotions evoked when listening to disliked music (Saarikallio & Erkkilä, 2007). Emotional arousal has also been found to influence taste intensity. Dess and Edelheit (1998) demonstrated that perception of saccharin bitterness increased after exposure to a mild stressor used as a negative emotional stimulus. Their results suggest that sensory evaluation can be influenced by emotions (Cabanac, 1992; Lang, 1995; Watson & Tellegen, 1985), supporting the notion that emotions can effect food perception.

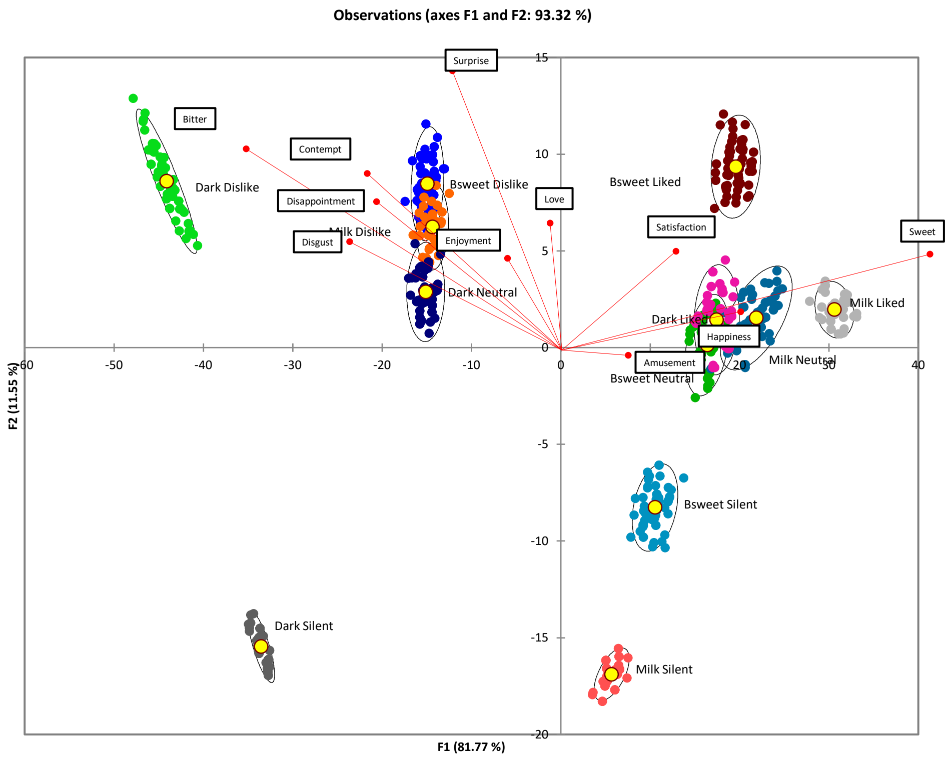

Figure 18. Canonical Variate Analysis Biplot of dominance durations of sensations. Hotteling-Lawley MANOVA test showed significant product differences ($F_{(121,5489)}$ = 4341.17; p < 0.05) based on sensory and emotional attributes.

Samples consumed with liked music were perceived *sweet*, and evoked *satisfaction* and *happiness* emotions. These results were similar to Jager et al. (2014) and Thomson, Crocker, and Marketo (2010), who demonstrated that sensory attributes such as *sweet* co-varied with the dynamics of positive emotions, for example, *interested*, *happy*, and *loving*. In addition, Platte et al. (2013) reported that subjects exposed to positive mood-inducing video clips rated citric acid solutions to be more acidic, sucrose solution to be sweeter, and quinine solution to be less bitter. In our study, chocolate gelati paired with disliked music were associated with *bitter* and elicited *surprise*, and other negative emotions including *contempt*, *disappointment*, and *disgust*. DC was associated with *bitter*, and evoked *disappointment* and *disgust* emotions. Similarly, Jager et al. (2014) reported that *bitter* was related to negative emotions like *bored*, *calm*, and *aggressive*. However, in our study, under the neutral music condition, BC and MC were perceived as being sweet, and elicited *amusement* and *happiness* emotions. These changes in emotions and mood may be explained by Macht and Mueller (2007) results, which demonstrated the immediate effects of eating chocolate on mood.

We propose that when music and gelati are congruent in terms of emotion, pleasure, and/or affective dimensions, panellists' hedonic and pleasantness ratings of the gelati may increase. However, when the music and the gelati are contextually incongruent, hedonic and pleasantness ratings may decrease. This music-elicited difference in overall impression of our gelati can be explained by using a concept of semantic congruency between music and food stimuli. Research (Demoulin, 2011) has shown that people appear to favour congruency (matching) of stimuli compared to incongruency (mismatching). For example, music congruency induces low arousal, leading to high pleasure (Demoulin, 2011). Mattila and Wirtz (2001) showed when background music was congruent with olfactory stimuli (e.g., lavender scent and slow tempo music) in terms of the arousal level, consumers evaluated the environment more positive. Hence it is recommended that during an evaluation of a food product, auditory cues or any other cues related to the product should be presented during trial. This will create an environment closely related to a situation where the product is consumed in a controlled laboratory environment. This will provide more ecological validity towards the product as it is being evaluated more closely to a real-life situation during product consumption (Sester et al., 2013).

Conclusion

This is the first study to show that taste perceptions of different chocolate flavoured gelati changed with music of different hedonic levels. Disliked music decreased pleasantness ratings of all chocolate gelati, elicited bitterness, and either eliminated or shortened sweetness sensations in gelati samples. Liked and neutral music, on the other hand, increased perceived pleasantness ratings for all chocolate gelati, with a concordant increase in sweetness perception. However, this was not the case for milk chocolate gelato (MC) and liked music, where not only sweetness perception was increased but bitterness perception was also absent throughout the trial. Such congruency effect may have taken into place (Demoulin, 2011) in the case of our MC as the liked sample paired with liked music. It may be that the final hedonic judgment of the gelati is partially influenced by the hedonic valence of the music but also the hedonic tone of the gelati itself.

This study demonstrated the crossmodal effect of music on temporal taste perception in laboratory controlled conditions. Hence to provide ecological validity of this crossmodal effect, it will be good to carry out this study in real eating environments. This is investigated in Chapter 6 of this thesis. It is also recommended that further investigation using objective physiological measures be carried out to observe the participant’s mood (emotion) state, instead of using self-assessed emotion scales, which would give a better understanding of the findings reported in this research. It is evident from this study that emotions were able to explain changes in sensory perception when listening to music varying in liking. It would also be worth investigating the temporal changes in emotions elicited by music while consuming gelati using temporal dominance of emotions in a separate trial (Jager et al., 2014).

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Chapter 6. The effect of music on food perception in different eating environments

Kevin Kantono[a], Nazimah Hamid[a*], Daniel Shepherd[b], Yi Hsuan Tiffany Lin[a], Charlotte Brard[c], Gianpaolo Grazioli[d], B. Thomas Carr[e,f]

[a] School of Applied Sciences, Auckland University of Technology, Private Bag 92006, Auckland 1142, New Zealand

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

[c] Agrocampus Ouest, 65 Rue de Saint Brieuc CS 84215, 35042 Rennes Cedex, France

[d] Giapo Ice Cream and Research Kitchen, 279-281 Queen St., Auckland 1010, New Zealand

[e] Carr Consulting, Wilmette, Illinois, USA

[f] Charles Sturt University, Wagga Wagga, NSW, Australia

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

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Abstract

This study highlights the effect of music varying in valence in different environmental conditions (laboratory, immersive, and natural eating environment) on the temporal changes in flavour perception. In addition, the pleasantness of three environments, individual affective state, and participants' emotional responses to chocolate gelato while listening to music were measured. The temporal perception of chocolate gelato in different eating environments were evaluated using the Temporal Check All That Apply under disliked, neutral, and liked music conditions, and a control (silent) condition. Results showed that *cocoaness*, *sweetness*, and *milkiness* were more cited in the natural eating environment than in laboratory setting, while *bitterness* and *creaminess* were the least cited. The cited attributes in immersive environment was similar to the natural eating environment. Music valence was found to consistently modify taste perception across the three environments. Liked and neutral music increased sweetness citations, whereas disliked music increased bitterness citations.

Introduction

The influence of music and sounds on food perception has received much attention lately. Researchers have investigated the effects of sounds using single instrumental sounds (Crisinel & Spence, 2009, 2010; Spence & Shankar, 2010), loud music (Ferber & Cabanac, 1987), jazz drums (Seo & Hummel, 2011), background music (Bailey & Areni, 2006; Dubé, Chebat, & Morin, 1995; Dubé & Morin, 2001; Kantono et al., 2015; Kantono et al., 2016), and soundscapes (Carvalho et al., 2016) to understand food perception. For example, crossmodal correspondences between taste themed music composed by music experts and basic tastes have been reported by Mesz, Trevisan, and Sigman (2011). They found that the salty and sweet musical pieces composed were associated with salty and sweet tastes respectively.

Fiegel, Meullenet, Harrington, Humble, and Seo (2014) was the first to demonstrate how music genre influenced perception of chocolate samples. They found that playing jazz music increased the overall impression and flavour pleasantness of chocolate. Kantono et al. (2015) demonstrated that hedonic judgements of gelato were in fact impacted by valence of different music genres. While listening to preferred music genre, the temporal pleasantness of chocolate gelati increased. Kantono et al. (2016) further examined temporal changes in taste with music varying in valence. They found that sweetness was dominant under neutral and liked music conditions, with corresponding positive emotions. On the other hand, bitterness was more dominant under disliked music condition, and elicited negative emotions. The emotion mechanism proposed by Woods et al. (2011) stated that heightened/valent emotion state influenced taste perception. Heath, Melichar, Nutt, and Donaldson (2006) demonstrated that heightened mood state increased sweetness, while decreasing perception of bitterness of tastant solutions. Platte, Herbert, Pauli, and Breslin (2013) further showed that sweetness of sucrose solution increased after watching an emotionally positive movie clip, while watching sad movie clip increased the bitterness of a quinine solution.

The eating environment where food is consumed is a key aspect that determines food acceptability. A review by Stroebele and De Castro (2004) emphasised the strong influence that ambience had on eating behaviour. Bell, Meiselman, Pierson, and Reeve (1994) also showed that customers selected and had higher acceptance for Italian food items (i.e. pasta) in an Italian themed restaurant. Since then more studies have confirmed the effects of eating environments on liking of food. Liking increased when wine was consumed at a reception (Hersleth, Mevik, Næs, & Guinard, 2003), salad, pizza and iced tea in a restaurant (King, Weber, Meiselman, & Lv, 2004), various foods in restaurant (Meiselman, Johnson, Reeve, and Crouch, 2000), and coffee in a virtual coffeehouse (Bangcuyo et al., 2015) and a cafetaria (Petit and Sieffermann, 2007). Jang and Namkung (2009) showed that better atmosphere and table service enhanced positive emotions, which in turn affected perception of food quality. Lin and Mattila (2010) had also highlighted that congruency (i.e., matching restaurant and food theme) had a positive impact on participants' food pleasantness ratings.

Boinbaser, Parente, Castura, and Ares (2015) highlighted that the Temporal Check All That Apply (TCATA) method overcomes the disadvantage of the Temporal Dominance of Sensations method, which only concentrates on the dominant sensations without considering the fact that other concurrent sensory attributes may exist over time. They had also reported TCATA to be compatible with untrained/semi-trained consumers. TCATA is a temporal method of defining the multiple sensory properties of products consumed over time. To date, TCATA has been widely used with consumer panels to evaluate cosmetic creams (Boinbaser et al., 2015), probiotic chocolate milk (Oliveira et al., 2015), and a variety of food products, including yoghurt, salami, cheese, juice (Ares et al., 2015).

This paper describes an extension of the research carried out by Kantono et al. (2016) and seeks to understand how music varying in valence influences temporal flavour perception of chocolate gelati when consumed in different environments (laboratory, immersive, and natural eating environment). Despite the rapid growth in this area of research there has however been a gap in understanding on how music can influence temporal flavour perception of food in different environments as previous studies had focused crossmodal interactions in laboratory controlled setting. We hypothesise that the temporal changes in flavour will be modulated with music valence in the different eating environments.

Materials and Method

Ethics Statement

The Auckland University of Technology Ethics Committee granted approval for this project. Participants were provided information sheets and had given prior consent prior to participating in the study.

Participants

A total of 259 participants were recruited. Participants were randomly allocated to participate in experiments in three different eating environments. Ninety participants (44 female, 46 male) aged between 21 and 37 years (M_{age} = 29; SD = 5.2) participated in the laboratory environment. Seventy-one participants (34 female, 37 male) between 21 and 47 years of age (M_{age} = 32; *SD* = 4.2) participated in the immersive environment study. Ninety two participants (52 female, 40 male) between 21 and 38 years of age (M_{age} = 31; *SD* = 2.4) participated in the real natural eating environment study. Participants recruited for each test environment were consumers of chocolate gelati, and received a monetary reimbursement for their participation.

Music Selection

Songs from different music genres were evaluated for liking similar to our previous studies (Kantono et al., 2015; Kantono et al., 2016). In brief, the downloaded songs were equalised in terms of amplitude prior to use in the experiment before rated for liking. The most liked and the least liked music samples were selected as liked and disliked music. In addition, neutral music was also selected from the music with a rating closest to the middle of the line scale. The presentation of disliked, neutral, and liked music selections to individual participants were randomised and counterbalanced.

Gelati Preparation and Presentation

Bittersweet gelato samples were purchased from a commercial establishment (Giapo) in Auckland. Gelato samples were transported and kept frozen overnight. Prior to serving, samples were tempered for one minute. A more detailed sample preparation and presentation are as described in Kantono et al. (2016).

Eating Environments

In the laboratory environment, the sound stimulus was delivered using headphones. For the immersive environment, consumers were invited to a gelato shop (Giapo) in central Auckland, New Zealand that was equipped with an isolated sensory dome that offered seclusion to the external environment (Figure 19). Participants were provided with a headset to receive the music stimulus, while the visual stimulus had an image of a gelato shop in Auckland displayed on the computer monitor within the dome. In the natural eating environment setting, participants were seated at the tables of the gelato shop and music was played through loudspeakers. Prior to TCATA testing, participants rated the valence (i.e., pleasantness) of all three eating environments using a 100 mm line scale.

Figure 19. The immersive environment (sensory dome) that was installed in the natural eating environment. The dome is lowered from the ceiling using a hoist. Inside the dome, consumers are able to experience music while consuming bittersweet gelato.

Emotional response to music

Prior to TCATA, participants' affective and emotional ratings were measured while listening to music varying in valence. In summary, participants rated their emotional response on an unstructured linescale based on 10 different emotions (*Amusement*, *Happiness*, *Enjoyment*, *Anger*, *Contempt, Disgust*, *Love, Surprise*, and *Satisfaction*) based on findings by Kantono et al. (2016). Definition of the emotional attributes and examples were also provided to participants (Table 9).

Table 9. Emotion attributes and descriptions used in this study

Sensory attributes	Valence	Event Example	Description
Anger	Negative	Entertained by restaurant' decor; Amused by the live music that the restaurant plays	Annoyance, displeasure, hostility
Contempt	Negative	The waiter was rude; Food was bad; Restaurant too noisy	Feeling of negative-ness, mean, vile, dishonoured
Disappointment	Negative	Dislike of people who eat junk food; I hate people who only consume meat	Sadness due to lack of fulfilment of expectations
Amusement	Positive	Fries are not crispy; Food was not good as expected	Enjoyment from an entertainment, or surrounding context and environment
Disgust	Positive	Oysters equal snot; Who would eat chicken feet?	Disapproval of something unpleasant and offensive
Happiness	Positive	I'm happy after my late lunch as I was hungry; I'm happy I've eaten healthy food; I'm very happy with this food	Feeling of pleasure and contentment
Enjoyment	Positive	I enjoy this food very much	Positive pleasure of having something good
Love	Positive	I love this signature dish from the restaurant; I love my ice cream in summer; I love champagne during a party	Intense affection
Satisfaction	Neutral	I'm satisfied after my late lunch; I'm very satisfied with the flavour of this food	Peaceful, happiness, calm, feeling when an outcome is above expectations

Temporal Check All That Apply (TCATA)

The TCATA procedure in this study adapted the protocol reported by Jager et al. (2014) to train participants with no experience in sensory analysis. The intensity scales were replaced with buttons that corresponded to the presence of sensory attributes. TCATA data was coded as binary values over time (0 for unchosen attributes and 1 for chosen attributes). Five out of 15 sensory attributes used to describe milk chocolate (Guinard & Mazzucchelli, 1999; Mazzucchelli & Guinard, 1999), were agreed on by a focus group that comprised of gelati consumers that best described taste, texture, and flavour of gelati. The attributes that were selected was sweetness, bitterness, cocoaness, milkiness, and creaminess. In this study, the TCATA protocol were adapted from the recommendations proposed by Pineau et al. (2012). A similar training approach by Kantono et al., (2015) was used where participants were provided: 1) demonstration videos, 2) familiarisation of attributes, 3) dummy trial for TCATA, and 4) panel leader actively checked if participants understood the procedure

Procedure

Consumetric TCATA measurements were carried out for the gelati consumed under three music conditions varying in liking, and a silent (reference control) condition in all three eating environments. During TCATA evaluation (see Figure 20) of sweetness, bitterness, milkiness, creaminess, and cocoaness attributes, participants selected the attribute choosing the appropriate button on screen. With perception of a new attribute, the corresponding button was selected. The participants may select the same attribute repeatedly or not select an attribute at all. Instructions on how to consume ice cream described by Kantono et al. (2016) was followed. Participants were provided detailed on-screen instructions on how to consume gelato at specified time points and when to take breaks during consumption of gelato over 45 seconds periods.

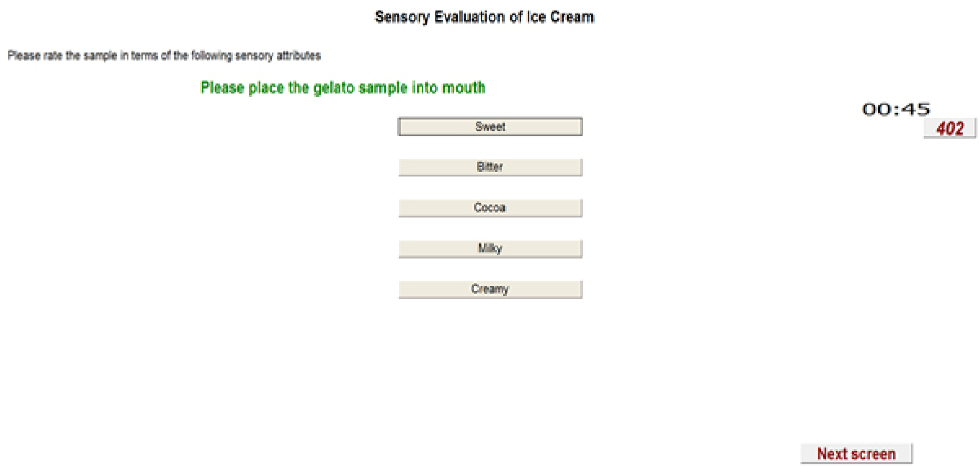

Figure 20. Representation of the consumetric TCATA screen.

Data analysis

Affective measures, emotional response, and pleasantness of eating locations

One-way repeated measures ANOVA ($\alpha=.05$) was carried out on participants' affective ratings, emotional responses, and perception of pleasantness of the three eating environments. Post hoc comparison using Tukey's was applied if statistical significance was noted.

Temporal Check All That Apply (TCATA) curves

Analysis of TCATA results were performed according to Castura et al. (2016) and Labbe, Schlich, Pineau, Gilbert, & Martin (2009). For each TCATA curve, reference lines were calculated to show the significant proportion of the curves selected not by chance, for each environment relative to other eating environments. Highlighted reference lines were plotted using the two-sided Fisher–Irwin test (Fisher, 1935; Irwin, 1935). The time of consumption was presented as standardized time according to Vidal et al. (2016) to better represent perception with greater panel consensus. Time standardisation was performed by using a score between 0 and 100, with 0 time when the line scale was clicked at start, and 100 when recording stopped automatically at 45 seconds.

Correspondence Analysis

In this study, Correspondence Analysis (CA) was employed to visualise the TCATA durations of selected sensory attributes. CA enabled the projection of sensory attributes onto a visual map (Castura et al., 2016). In addition, test of independence between rows and columns (using chi-square analysis) determined if significance in terms of sensory perception existed with different music and environment.

Multiple Factor Analysis

MFA examined similarities between the cited sensory perceptions of gelati with music type in different eating environments. For each eating environment, the duration for each sensory attribute was calculated and used in MFA analysis. Random Variable (RV) coefficients allowed the comparison of sample configurations in the three eating environments. Higher RV coefficients indicate higher degree of participant similarities (Balbas et al., 2015). The data format for MFA is provided in Figure 21.

Music	Lab Environment			Immersive Environment			Natural Eating Environment		
	Attribute 1	…	Attribute 5	Attribute 1	…	Attribute 5	Attribute 1	…	Attribute 5
Liked									
Disliked									
Neutral									
Control									

Figure 21. Data structure for Multiple Factor Analysis.

Results

Pleasantness of eating locations

Significant differences in pleasantness of the three different eating locations ($F_{(2,\ 773)} = 943.11$; $p < .05$) were observed. Post-hoc Tukey comparison showed that the natural eating environment (Mean ± Standard Deviation; 92.2 mm ± 5.7) was significantly more pleasant than the immersive environment (86.7 mm ± 6.3). The immersive environment in turn was significantly more pleasant compared to the laboratory environment (51.3 mm ± 4.9).

Affective ratings of music varying in liking

Significant differences were observed in terms of emotional responses to music that varied in individual liking (Figure 22). Differences were observed in valence ($F_{valence(2, 773)} = 124.21$; $p < .05$), and arousal ($F_{arousal(2, 773)} = 78.41$; $p < .05$), but not dominance ($F_{dominance(2, 773)} = 1.43$; $p = .239$). Disliked music was perceived to be significantly more arousing (79.7 ± 3.2), and significantly less valent (21.2 ± 2.9) than neutral and liked music conditions. Liked music was however significantly less arousing (31.5 ± 4.4), but more valent (92.1 ± 5.3) compared to disliked and neutral music.

Significant differences were observed in terms of the emotional state elicited by music that varied with liking (Figure 23). Liked music evoked significantly higher ratings of positive related emotions (*satisfaction, happiness, amusement, love, and enjoyment)* compared to neutral and disliked music. Disliked music evoked significantly higher ratings of negative emotions namely *contempt*, *disgust*, and *disappointment* compared to neutral and liked music.

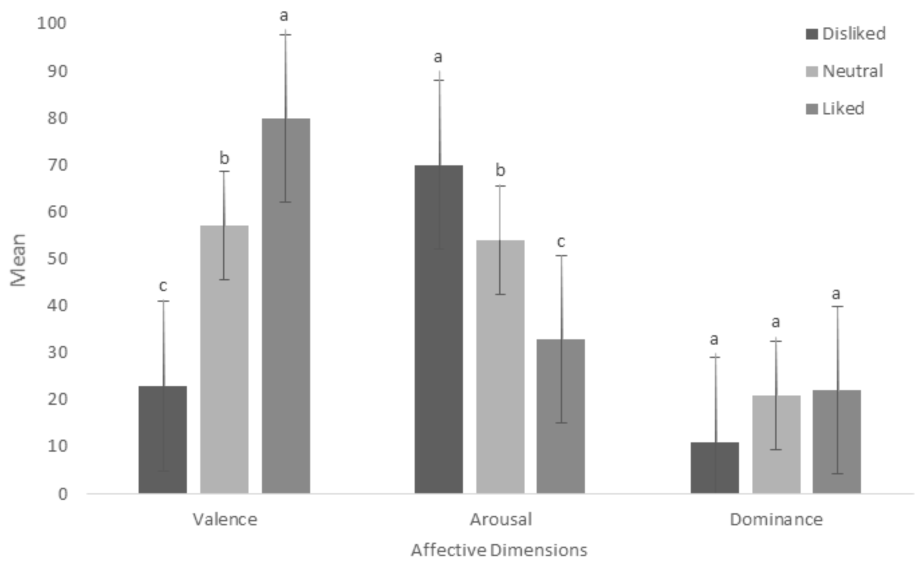

Figure 22. Differences in valence, arousal, and dominance of music varying with liking. [a,b,c]: mean affective ratings of music varying in liking with different letters significantly differ in terms of affect dimensions.

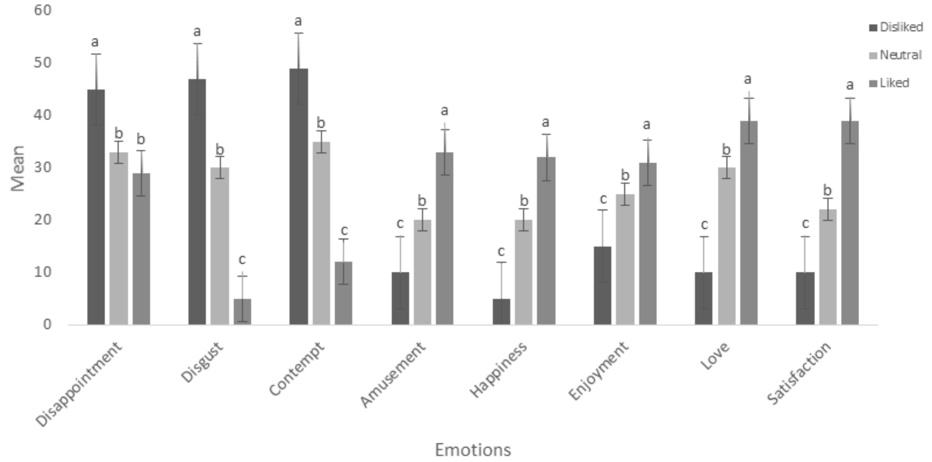

Figure 23. Differences in emotional responses to music varying in liking. [a,b,c]: mean emotion ratings of music varying in liking with different letters significantly differ in terms of emotions.

TCATA curves

Control condition

Figure 24 illustrates the smoothed TCATA curves for samples consumed in the control (silent) condition. Cocoaness was highly cited in the natural eating environment, with an increase observed between 5 – 25% standard time (ST), reaching a maximum citation rate of 61% that then decreased until 52% ST. Cocoaness was the next most cited in the laboratory environment, where it increased from 44 – 56% ST, reaching a maximum citation rate of 55%, which then decreased until 78% ST. Cocoaness was least cited in the immersive environment, with a decrease between 30 – 56% ST from a maximum citation rate of 60%.

Sweetness was highly cited in the natural eating environment with an increase between 48 – 82% ST, reaching a maximum citation rate of 38%. This was followed by the immersive environment, where sweetness increased from 0 - 44% ST, and increased from 78 – 80% ST, reaching a maximum citation rate of 30%. Sweetness was least cited in the laboratory environment, decreasing from a maximum citation rate of 30% between 13 – 58% ST, and slowly increasing until 68% ST.

Bitterness was most cited in the laboratory environment, reaching a maximum citation rate of 29% between 0 – 12% ST. It then hovered between 8 – 19% citation rate between 21 - 100% ST. Bitterness was less cited in the immersive environment, with an increase between 56 – 78% ST and reaching a maximum citation rate of 20%. Bitterness was the least cited in the natural eating environment, and decreased from a maximum citation rate of 18% between 0 - 24% ST.

Milkiness was the most cited in the natural eating environment, decreasing from 15 - 22% ST, but later increasing until 41% ST, and reaching a maximum citation rate of 28%. This was followed by the laboratory environment, where milkiness decreased from 24% maximum citation rate between 25 - 30% ST. In the immersive environment, milkiness was the least cited, decreasing from 18% maximum citation rate between 30 - 38% ST, and hovered between 9 - 12% citation rate until end of the mastication period.

Creaminess was the most cited in the laboratory condition, and increased between 0 – 21% ST, reaching a maximum citation rate of 30%. It then decreased between 40% - 69% ST, but later increased until 85% ST to a maximum citation rate of 30%. This was followed by the immersive environment, where creaminess increased between 10% – 32% ST at 19% citation rate. Creaminess was the least cited in the natural eating environment with a maximum citation rate of 11% in the early mastication period (0 – 7% ST and 28 – 32% ST) and hovered between 8 – 12% citation rate throughout the mastication period (35 – 100% ST).

Liked music

Figure 25 illustrates the smoothed TCATA curves for samples consumed under the liked music condition. In the natural eating environment, cocoaness was the most cited, increasing between 11 - 50% ST, and reaching a maximum citation rate of 58%. However cocoaness was less cited in both immersive (65 – 85% ST) and laboratory (49 – 73% ST) environments.

In the natural eating environment, sweetness was the most cited, increasing between 70 – 72% ST, reaching a maximum citation rate of 52%, and then decreased between 75 – 91% ST. Sweetness was next most cited in the immersive environment, initially decreasing until 16% ST, increasing up to 59% ST, and then reaching a maximum 43% citation rate. In the laboratory condition, sweetness was the least cited and increased between 20 - 100% ST, with a maximum citation rate of 41% at 54% ST.

Bitterness was the most cited in the laboratory condition and increased between 0 – 11% ST, reaching a maximum citation rate of 37%. It then hovered between 9 – 18% citation rate for between 33 – 77% ST. In the immersive environment, bitterness increased from 34% ST and reached 30% maximum citation rate at 98% ST. Bitterness was the least cited in the natural eating environment, being cited only between 14 – 62% ST, and hovered between 2 – 15% citation rate.

Milkiness was most cited in the natural eating environment, slowly increasing between 0% - 67% and 73% - 83 % ST, and reaching a maximum citation rate of 20% at 83% ST. It was next most cited in the immersive environment, increasing from 58 – 82% ST, and reaching a maximum citation rate of 20%. Milkiness was the least cited in the laboratory environment.

Creaminess was most cited in the laboratory environment from 0 – 30% ST, reaching a maximum citation rate of 35%, and then decreased in citation until 58% ST. It was less cited in the immersive environment, increasing from 40 – 58% ST, and reaching a maximum citation rate of 11%. In the natural eating environment, creaminess was the least cited, increasing from 0 - 31% ST, and hovered thereafter between 8 - 11% citation rate.

Disliked music

Figure 26 illustrates the smoothed TCATA curves for samples consumed under the disliked music. In the natural eating environment, cocoaness was the most cited and decreased from a maximum citation of 50% between 0 - 16% ST, and was again cited between 50 - 70% ST. Cocoaness was next most cited in the laboratory environment, decreasing from 35% citation rate between 56 - 71% ST. Cocoaness was the least cited in the immersive environment throughout the mastication period.

Sweetness was the least cited attribute in all three environments with disliked music. It was cited in the natural eating environment from 0 - 43% ST and 50 - 79% ST, reaching a maximum citation rate of 22% between 60 – 70% ST. In the immersive environment, sweetness was cited throughout the mastication period (0 – 100% ST), reaching a maximum citation rate of 19% at 38% ST, which decreased thereafter until 8% citation rate. Sweetness was cited in the laboratory environment decreasing from the maximum citation rate of 18% between 0 - 18% ST.

Bitterness was the most cited in the laboratory environment, increasing from 10 - 40%, 45 - 52%, and 80 - 100% ST, and reaching a maximum citation rate of 69% at 98% ST. In the immersive environment, bitterness was next most cited from 3 - 19% ST reaching a maximum citation rate of 49%, increasing between 35 - 62% ST to reach a maximum citation rate of 35%, and finally decreasing from 62 – 70% ST. In the natural eating environment, bitterness was the least cited and increased from 36 - 79% ST, reaching a maximum citation rate of 28% that then decreased until 88% ST, and finally hovered between 20 – 22% citation rate until 100% ST.

Milkiness was significantly most cited in the natural eating environment with a maximum citation rate of 39% (between 21 - 30% ST). Milkiness was less cited in the immersive (30% citation rate; decreasing from 20% ST) and laboratory (28% citation rate; between 62 - 69% ST) environments.

Creaminess was the most cited attribute in the laboratory environment, increasing from 0 - 20% ST, and reaching a maximum citation rate of 12% ST. It then decreased from 35% citation rate between 75 - 90% ST. Creaminess next increased in the immersive environment from 0 - 18% ST, reaching a maximum citation rate of 30% between 28 – 30% ST, and then decreasing between 30 - 45% ST. Creaminess was the least cited in the natural eating environment, with a citation rate of between 6 - 8%, between 60 - 100% ST.

Neutral music

Figure 27 illustrates the smoothed TCATA curves using spline equation for samples consumed under the neutral music condition. In the natural eating environment, cocoaness was the most cited decreasing from 35 – 38% ST, increasing from 38 - 42% ST to a maximum of 50% citation rate, decreasing from 50 – 62% ST, and increasing between 62 – 72% ST reaching a maximum citation rate of 32%. In the immersive environment, cocoaness was cited between 30 - 33%, 40 - 51%, and 59 - 62% ST, only increasing between 73 - 78% ST to a maximum citation rate of 49%, and then decreased until 96% ST. Cocoaness was the least cited in the laboratory environment, increasing from 15 - 43% ST, and reaching a maximum citation rate of 39% at 33% ST.

Sweetness was significantly most cited in the natural eating environment and increased from 0 - 100% ST, reaching a maximum citation rate of 48% at 58% ST, and decreasing thereafter between 22 – 30 % citation rate. In the immersive environment, sweetness was only cited from 12 - 53% ST, slowly increasing from 58 - 69% ST to reach a maximum citation rate of 36%, ST, and then decreasing between 71 - 88% ST to about 12% citation rate. In the laboratory environment, sweetness was the least cited, and was cited from 52 - 60%, 68 – 75%, and 95 – 100% ST.

For the laboratory environment, bitterness was cited between 40 - 50% ST reaching a maximum citation rate of 30%. In the immersive environment, bitterness decreased from 10 – 40% ST from 30% citation rate, and was further cited between 73 – 90% ST. Bitterness was only cited between 40 – 78% ST with citation rate between 2 – 10%.

In the natural eating environment, milkiness was the most cited attribute throughout the mastication period. It increased to a maximum citation rate of 47% between 0 – 40% ST, which thereafter decreased from 48 – 100% ST. In the immersive environment, milkiness was cited between 0 - 65% ST, reaching a maximum citation rate of 40% at 18% ST, which then decreased. In the laboratory environment, milkiness was the least cited. It increased until 16% ST, reaching a maximum citation rate of 20%, and then decreased between 80 - 100% ST.

In the laboratory environment, creaminess was the most cited, increasing between 24% - 62% ST, reaching a maximum citation rate of 49%, which then later decreased from 72% ST until the end of mastication. In the immersive environment, creaminess decreased from a maximum citation rate of 29% between 26% - 70% ST. In the natural eating environment, creaminess was only cited between 35 - 90% ST, with citation rates between 11 - 22%.

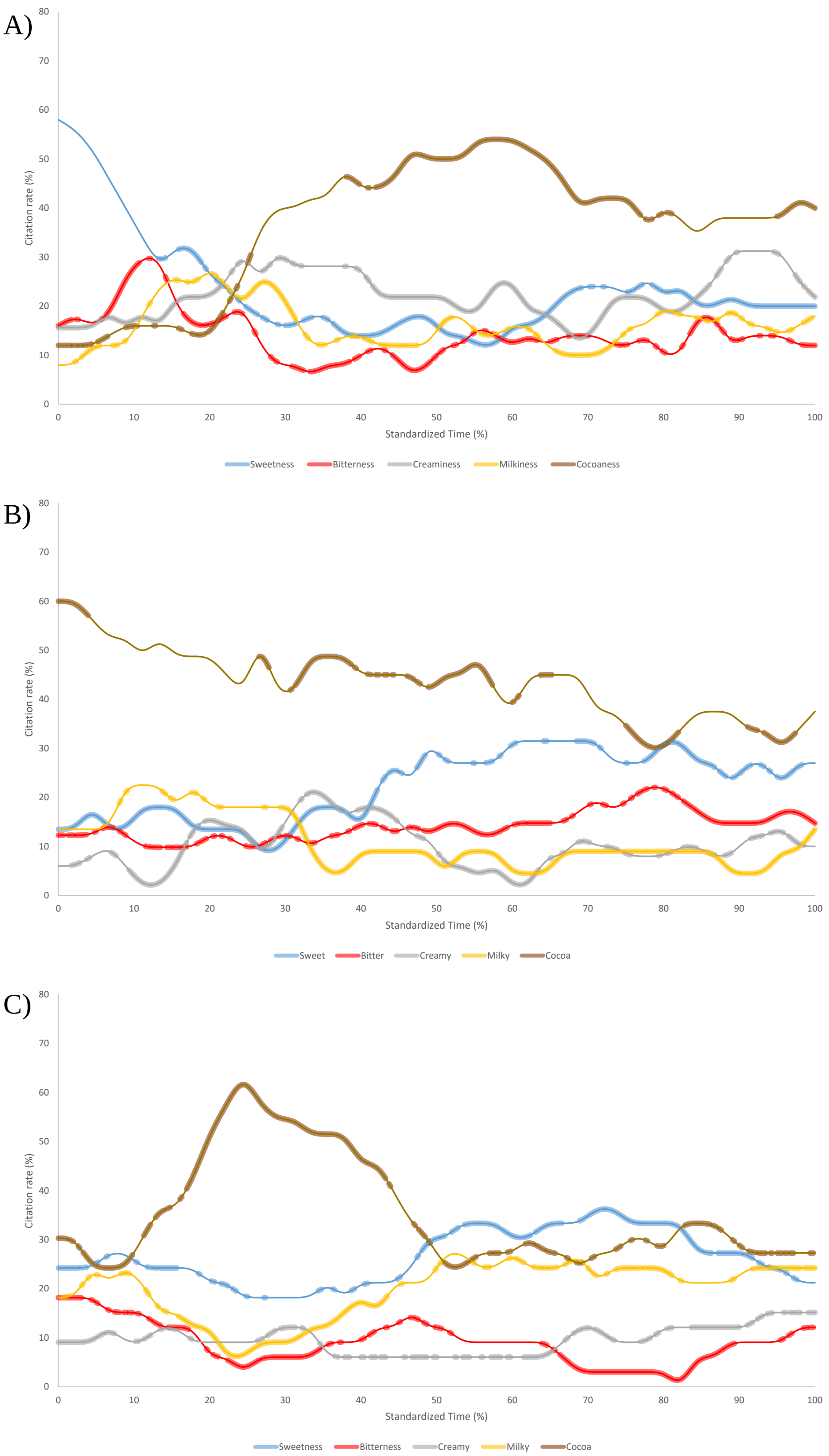

Figure 24. TCATA curves for chocolate gelato consumed in different environments under the control condition: A) Laboratory B) Immersive and C) Natural eating environment. Reference lines (highlighted) indicates that citation proportions were not based by chance.

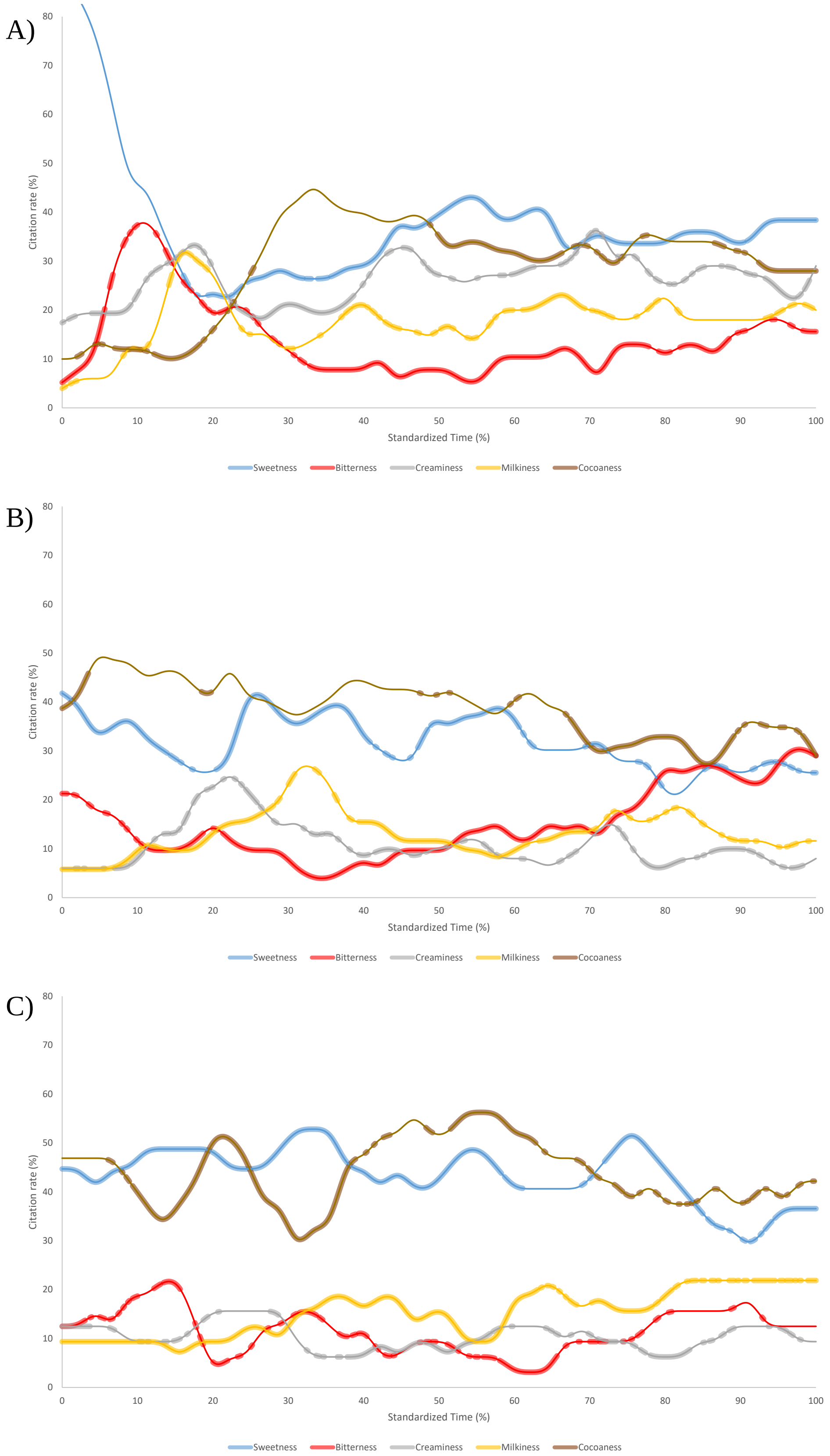

Figure 25. TCATA curves for chocolate gelato consumed in different environments under the liked music condition: A) Laboratory B) Immersive C) Natural eating environment venue. Reference lines (highlighted) indicates that citation proportions were not based by chance.

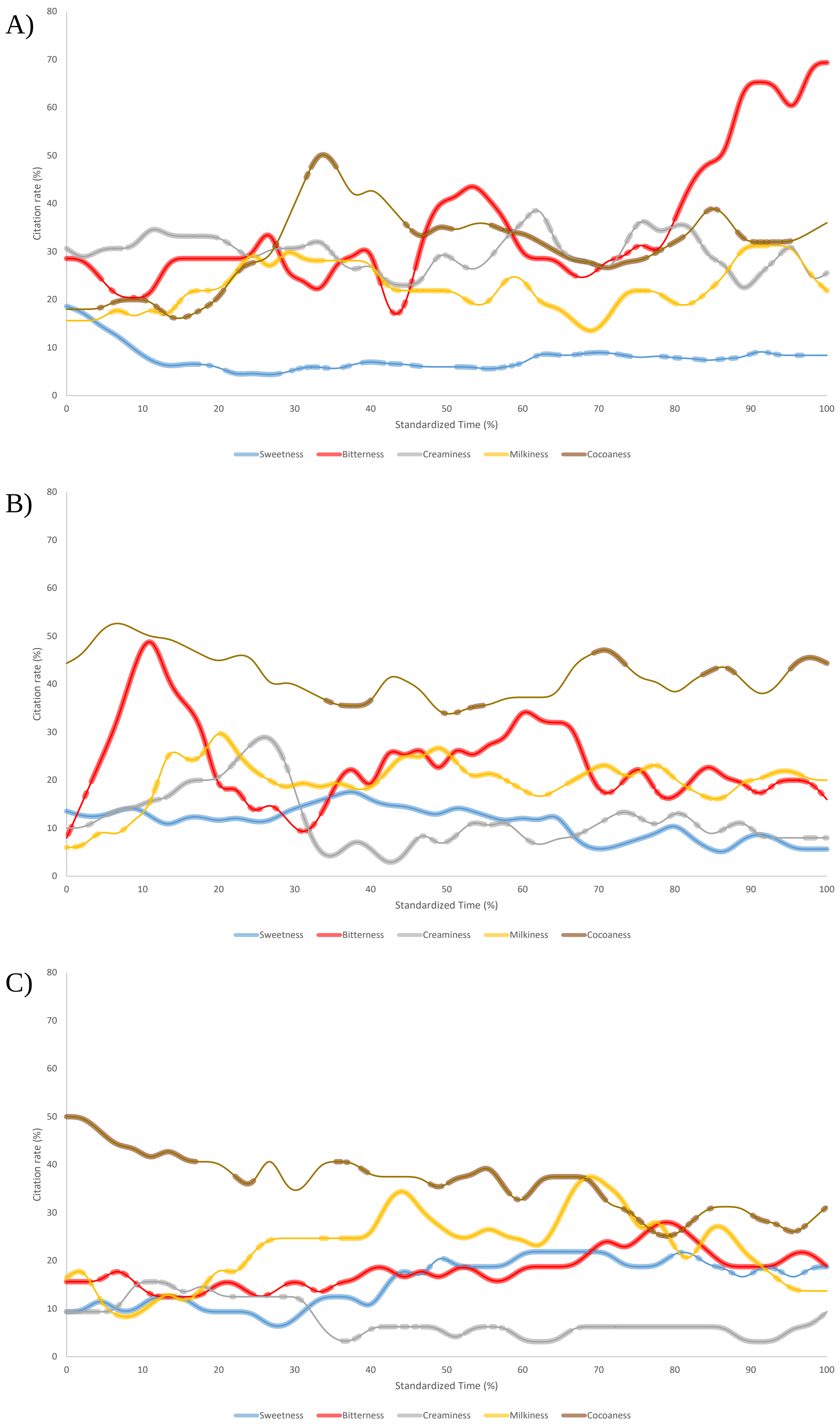

Figure 26. TCATA curves for chocolate gelato consumed in different environments under the disliked music condition: A) Laboratory B) Immersive C) Natural eating environment. Reference lines (highlighted) indicates that citation proportions were not based by chance.

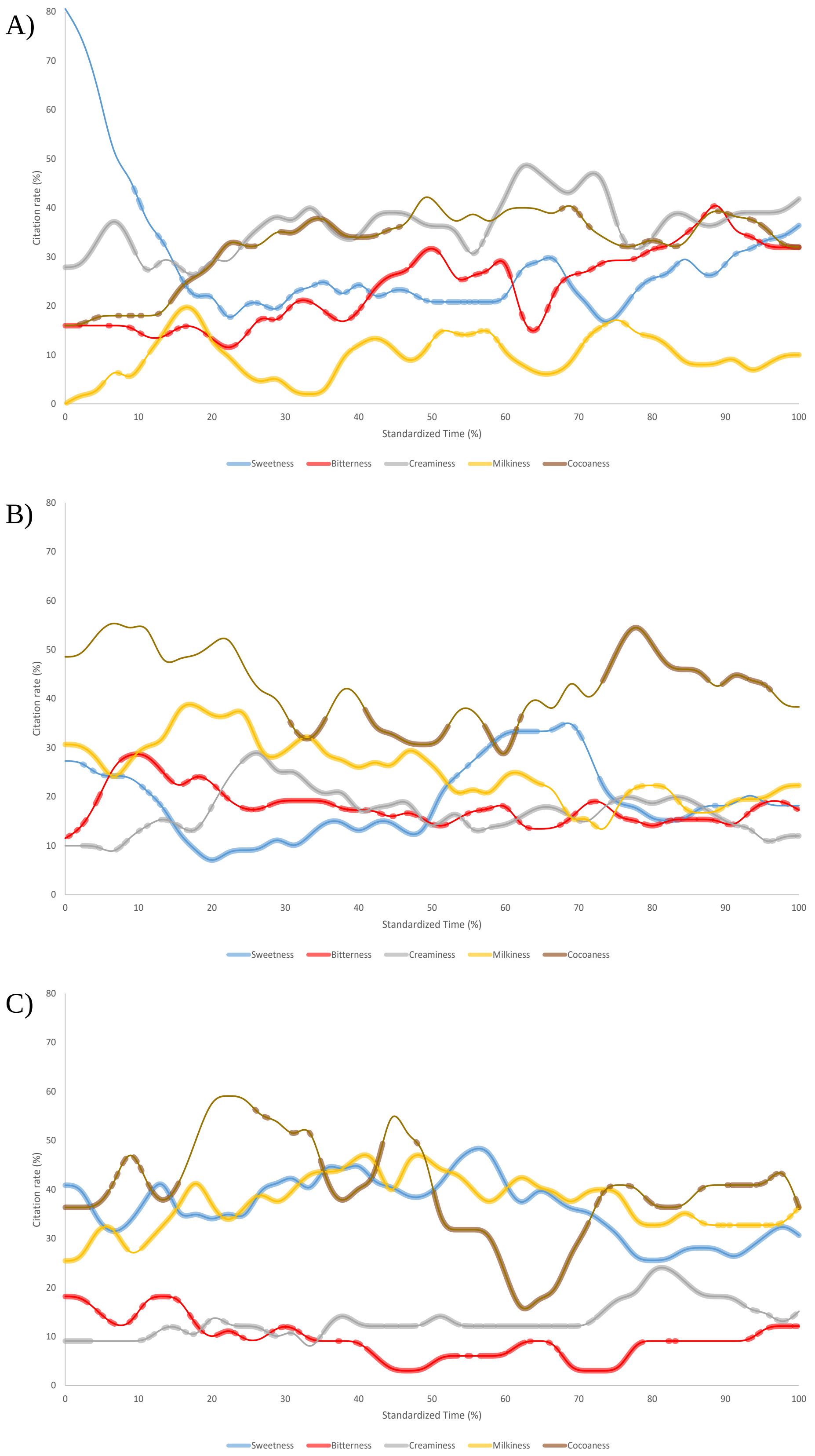

Figure 27. TCATA curves for chocolate gelato consumed in different environments under the neutral music condition: A) Laboratory B) Immersive C) Natural eating environment. Reference lines (highlighted) indicates that citation proportions were not based by chance.

Correspondence Analysis

Significant differences were observed in terms of sensory perception of gelati with different music and environments ($X^2_{(44)}$ = 60.48; p < .01). The correspondence analysis map (Figure 28) showed a clear separation of silent, and neutral, liked and disliked music conditions along the first factor. Listening to disliked music were associated with creaminess and bitterness. Listening to liked music was associated with sweetness, while neutral music was associated with milkiness and cocoaness.

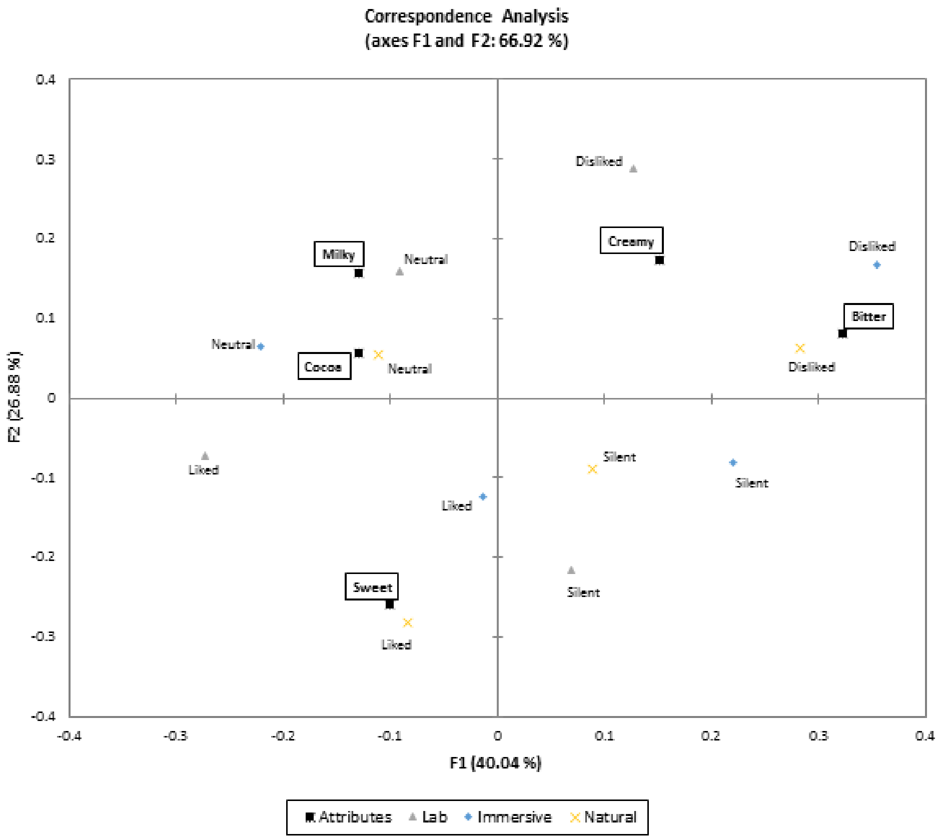

Figure 28. Correspondence Analysis factor map (first two components) based on aggregated TCATA data for the whole evaluation duration. The different shapes represent the three different environments (laboratory, immersive, and natural).

Multiple Factor Analysis

Points corresponding to the natural eating environment and immersive environment were close compared to the laboratory environment under all music and control conditions (Figure 29). The RV coefficients for the three environments were in the range of 0.61 and 0.7, indicating some degree of similarity between all three environments. The immersive and natural eating environment (RV = 0.7) was found to be the most similar. The laboratory and immersive environments (RV = 0.66) were the next most similar environments. The laboratory and the natural eating environment were the least similar (RV = 0.61).

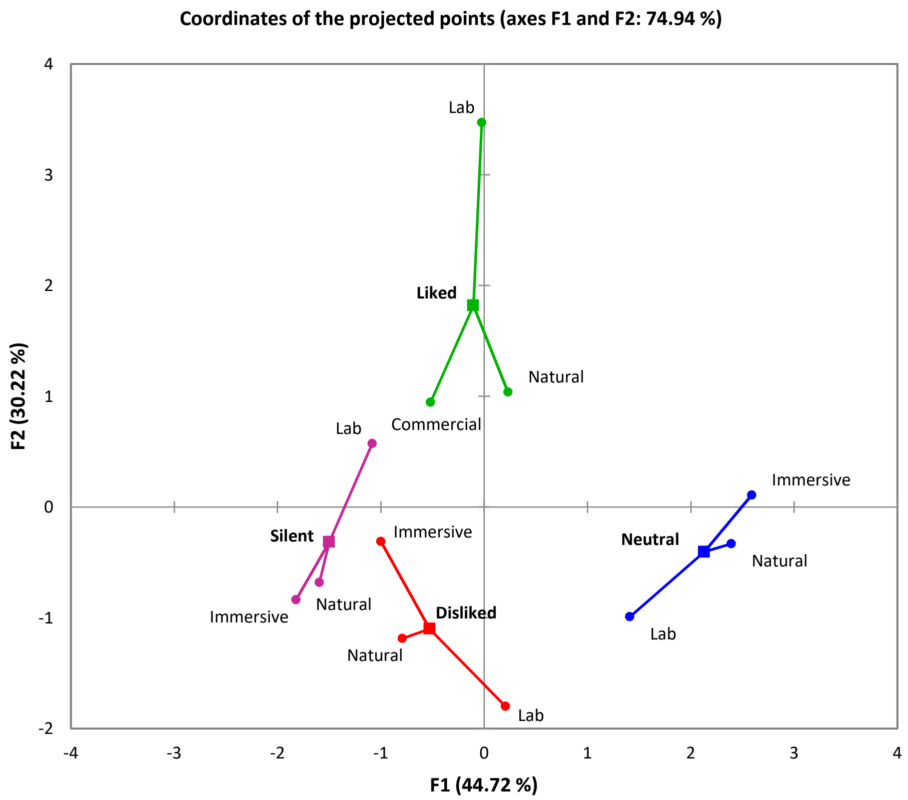

Figure 29. Consensus Multiple Factor Analysis sample space (first two components) with superimposed partial points from individual eating environment. The different colours represent the music/control conditions: disliked music (red); neutral music (blue); liked music (green), and; control (silent) condition (purple).

Discussion

Differences in pleasantness of eating locations

The three eating environments in this study differed in terms of pleasantness, where the most pleasant was the natural eating environment that was followed by the immersive and laboratory environments. Bangcuyo et al. (2015) demonstrated participants were able to differentiate coffee samples based on liking in the immersive environment (i.e. virtual coffeehouse) compared to traditional sensory booths. Meiselman et al. (2000) also reported that participants had higher liking and sensory acceptance of various foods (i.e., pasta, dessert, beverage, etc.) in a restaurant setting compared to laboratory condition. In both studies, consumption in a simulated or natural eating environment was shown to increase liking.

Affective and emotional responses evoked by music

This study confirmed that liked and disliked music evoked emotions similar to Kantono et al. (2016). Liked music evoked significant positive emotions, while disliked music evoked significant negative emotions. Differences in emotions evoked by music can be explained as emotions are governed by valence and arousal according to Posner et al. (2005). Concordant with our findings, Konečni (2008) reported that listening to high valence and low arousal music evoked positive emotions, while low valence and high arousal music evoked negative emotions.

Temporal Check All That Apply

Cocoaness

Cocoaness was the first cited attribute followed by sweet and then bitter in both immersive and commercial environments, but not in the laboratory. Similarly Petit and Seiffermann (2007) found that coffee flavour was cited higher while taste attributes (i.e. bitter) were less cited in a cafeteria compared to the laboratory setting. Coffee that was consumed in natural eating environments (meeting room and cafeteria) showed higher frequency citations of coffee flavour compared to the laboratory setting. Meiselman et al. (2000) further reported that chocolate mousse dessert was more liked in terms of flavour in the training restaurant compared to the dining hall.

However, with disliked music, cocoaness was shown to be most cited in the natural eating environment, followed by the laboratory, and immersive environment. The decrease in cocoaness in the immersive environment only occurred while listening to disliked music. Listening to disliked music can decrease the pleasantness of chocolate gelato (Kantono et al., 2015). Other studies however, only examined overall liking and acceptance of food in different eating environments (King et al., 2004; Edwards et al, 2003). They found that eating food samples in a restaurant setting significantly increased liking of food samples compared to the laboratory setting.

In the laboratory environment, attributes were perceived in the order of sweet, bitter and cocoa. Similarly, TDS studies in the laboratory setting have shown that taste evolved first, followed by flavour. Semi-solid food matrices like gels (Labbe et al., 2009) and 15% gelatin soft candies (Saint-Eve et al., 2011), elicited taste attributes first (i.e., sweetness, bitterness, and sourness) followed by flavour attributes (i.e., peach, mint, and strawberry).

Sweetness

For bittersweet gelato, sweetness was highly cited in the natural eating environment, and least cited in the laboratory environment for all music conditions. Sweetness of chocolate gelato was enhanced in the natural eating environment where gelato was sold. Similarly, Petit and Sieffermann (2007) showed that milk coffee was cited sweeter and more liked in a natural eating environment compared to the laboratory.

Listening to liked music showed the highest maximum citation frequency for temporal sweetness perception in all three environments. In our study, liked music evoked positive emotions (*re:* Figure 5). Similarly, Kantono et al. (2016) showed that liked music increased the dominance of sweetness, which was correlated with positive emotions. In a study by Heath et al. (2006) participants were administered systemic monoamines to evoke a high valent state. They reported a lower sucrose threshold and higher bitterness threshold of tastants solutions in the valent state.

Bitterness

Bitterness was highly cited in the laboratory environment followed by the immersive and natural eating environments in all music conditions. Petit and Sieffermann (2007) similarly reported that coffee samples were cited less bitter in a cafeteria environment compared to a laboratory environment. They also found that bitterness was the least chosen attribute while consuming coffee in a natural cafeteria environment.

Listening to disliked music amplified perceptions of bitterness in all three environments relative to the control condition similar to Kantono et al. (2016). Pertinently, listening to disliked music in our study evoked negative emotions (*re*: Figure 5). Platte et al. (2013) also showed an increased rating of bitterness after participants saw a negative mood video (i.e. sad films) clip. Hence, the increase in bitterness in this study might be explained by the mood mechanism proposed by Woods et al. (2011).

Milkiness

The temporal perception of milkiness had higher citations in the natural eating environment followed by immersive and laboratory environments for liked, disliked, and neutral music conditions. Although milkiness varied in the three environments, these differences were small in terms of citation rates (5-8% citation rate). This finding is supported by Petit and Sieffermann (2007) who also observed small differences in the milkiness of coffee. They found milkiness only showed an increase in milk description frequency by 1.2% in the laboratory compared to a cafeteria.

Playing neutral music resulted in a higher milkiness citation rate throughout the mastication period in all three environments compared to the control condition. Milkiness had a higher citation frequency in immersive and real natural eating environments, while listening to neutral, as opposed to liked or disliked, music. Kantono et al. (2015) showed that chocolate gelati was rated most pleasant with neutrally preferred music compared to preferred and non-preferred music. This might be due to the attentional effect of neutrally preferred music that may have likely phased out of awareness according to Madsen (1987), and thereby increasing cognitive capacity for food assessment.

Creaminess

Creaminess was less cited in the natural eating environment compared to the immersive and laboratory environments for all music conditions. According to the extended M-R model, the overall pleasantness and consumption experience of a consumer is heavily influenced by the eating environment and servicescape (i.e., the physical facilities of a service company) of the environment (Lin & Mattila, 2010). Jang and Namkung (2009) reported that a positive atmosphere would evoke positive emotions, which in turn influences consumers' behavioural intentions. Creaminess is a textural attribute that is linked to fat. A study by Torres and Nowson (2007) demonstrated that, under stressful conditions, participants would crave fatty food. Similarly to Platte et al. (2013) participants under negative mood had shown to rate higher fat perception compared to those in positive or neutral mood. Therefore, the lowered citation frequency of creaminess sensations in the natural eating environment can be explained by the positively induced mood in participants in the real eating environment as compared to the immersive or laboratory environment.

Listening to disliked music resulted in a higher citation frequency of creaminess only in the laboratory environment. The higher citation rate of creaminess perception compared to the other music and control conditions was perhaps due to the desire of the participants for fat while exposed to a mild stressor (i.e. disliked music). Hence, we postulate that the stressor (disliked music) may have influenced our participants to crave or perceive fat while listening to disliked music only in the laboratory environment, which was the significantly least pleasant environment of the three environments investigated.

Overall effect of music in different environments

Correspondence Analysis (CA) supported TCATA curves in our study. Listening to different music influenced flavour perception of gelati. Liked and disliked music evoked sweetness and bitterness taste respectively similar to our previous study (Kantono et al., 2015; Kantono et al., 2016). In addition, this current study was the first to show the association of flavours with music in contrary to previous findings by Crisinel (2010) who found weak/no associations between flavour tastants (i.e. vanilla, rose, coffee) and pitch tones. In our study, listening to neutral music increased the perception of milkiness and cocoaness. In addition, creaminess increased while listening to disliked music.

Multiple Factor Analysis (MFA) revealed that the natural eating environment and immersive environment were more similar (RV = 0.7) than the laboratory environment under the three music conditions (RV = 0.61). This can be explained as both the immersive and natural eating environments were both significantly more pleasant compared to the laboratory environment in terms of pleasantness (Section 4.1). A review by Stroebele and De Castro (2004) reported numerous studies investigating the effects of the eating environment in isolation (i.e. music/lighting) with the focus on liking/acceptance of food. Our study is the first to assess the crossmodal interaction of music varying in valence affects temporal food flavour perception in varying eating environments.

Conclusion

The natural eating environment was found to be the most pleasant environment. Cocoaness, sweetness, and milkiness attributes were the most cited attributes in the order of natural eating environment > immersive environment > laboratory environment. Results from correspondence analysis further showed associations between liked music and sweetness; neutral music and milkiness and cocoaness; disliked music and bitterness across all three environments. The immersive environment and natural eating environment were found to be similar in terms of sensory attributes as a function of music conditions.

Although TCATA was easier to use for consumer panels, it did not measure dominance of each attribute. Hence, TCATA only provided overall perceived temporal sensations during eating. As the present study only investigated the effect of auditory cues towards flavour perception, further studies on temporal texture perception is recommended. Future studies on multi-intake TCATA and corresponding measures of hedonic ratings using a realistic serving portion may further provide real life validity of the results obtained in this study.

It is also recommended that further investigation using physiological measures to understand participant's mood (emotion) state, in addition to using self-assessed emotion scales. This will provide a more objective measure that can further validate the role of mood mechanism in explaining the crossmodal effect between music and food. This is investigated in research carried out in Chapter 7 of this thesis.

Acknowledgment

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Chapter 7. Emotional and electrophysiological correlates of flavour perception in the presence of music

Kevin Kantono[a], Nazimah Hamid[a*], Daniel Shepherd[b], Yi Hsuan Tiffany Lin[a], Selma Skiredj[c], B. Thomas Carr[d,e]

[a] School of Applied Sciences, Auckland University of Technology, Private Bag 92006, Auckland 1142, New Zealand

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

[c] Agrocampus Ouest, 65 Rue de Saint Brieuc CS 84215, 35042 Rennes Cedex, France

[d] Carr Consulting, Wilmette, Illinois, USA

[e] Charles Sturt University, Wagga Wagga, NSW, Australia

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

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Abstract

The influence of sound and music upon flavour perception has been of interest lately. Potential mechanisms explaining multisensory interactions include distracted attention, emotional arousal, and changes in mood state. In this study, Temporal Dominance of Sensations (TDS) was utilised evaluate change in the taste and flavour of chocolate gelato while listening to music. Participants rated their emotion following after each TDS trial by intensity scales. In addition, cardiovascular, respiration, and electrodermal electrophysiological parameters were measured. As anticipated, listening to liked music evoked positive emotions (*enjoyment, happiness, love, and satisfaction*), while disliked music evoked negative emotions (*disappointment, and disgust*). No significant difference in terms of RESP was observed while listening to music differing in liking. Listening to disliked music showed highest significant change in SC, compared to neutral and liked music. Neutrally liked music significantly decreased BVP amplitude, while listening to liked music significantly increased HR. Partial Least Square Regression (PLSR) was applied to explore the relationship of electrophysiological and sensory measures. Electrodermal and cardiovascular measures predicted the liking of gelato. Partial Least Square Path Modelling (PLS-PM) was utilised to investigate the relationships between the electrophysiology measures, subjective emotion ratings, and perception. Changes in cardiography (BVP and HR) and electrodermal (SC) measures were correlated with subjective rated emotions. Furthermore, emotions evoked by music varying in liking were correlated with flavours.

Introduction

A review by Macht (2008) exploring how emotions affected consumers' eating behaviour highlighted the importance of emotional states on food choice and intake. Desmet and Schifferstein (2008) showed that emotions elicited by eating were mainly influenced by the food's valence (i.e., pleasantness). Torres and Nowson (2007) reported that participants exposed to stressors tend to select fatty foods. Platte, Herbert, Pauli, and Breslin (2013) found that viewing a sad movie resulted in higher ratings of perceived fat in dairy solutions, and lower ratings of sweetness of sucrose solutions. Studies have also demonstrated that mildly stressed participants showed higher bitterness ratings of saccharin solution (Dess & Edelheit, 1998), and lowered sweetness ratings of sucrose solution (Al'absi, Nakajima, Hooker, Wittmers, & Cragin, 2012).

Emotion can be explained broadly as the variations in both psychological and physiological processes that accompany exposure to an object or internal / external events. According to the emotion circumplex model, emotions are separated into arousal (activation-deactivation) and valence (pleasant-unpleasant). Valence can be referred to as the perceived attractiveness (joy) or aversiveness (anger) of an object or event, while arousal attributes is the strength of an urge to move toward or away from a stimulus. Music can evoke positive affective states (traits or temperaments) such as *goodness*, and *friendliness* (Eifert, Craill, Carey, & O'Connor, 1988), or negative emotions (*bad feeling*, and *unpleasantness*) (Blair & Shimp, 1992). Listening to liked music activates the brain areas that evokes positive emotion (Brown, Martinez, & Parsons, 2004). Contrariwise, listening to disliked music supresses activity in the brain areas associated with reward (Pereira et al., 2011). Kantono et al. (2015) were the first to report the influence of valence of gelati as a function of music varying in self-rated liking. Music that are neutrally preferred resulted in significantly increased ratings of pleasantness chocolate gelati in comparison to preferred and non-preferred music. They went on to demonstrate that liked music was correlated to sweetness dominance of chocolate gelati, while disliked music increased the duration of bitterness dominance (Kantono et al., 2016). Sweetness was correlated with positive emotions evoked by liked music, while bitterness was correlated with negative emotions evoked by disliked music.

Broadly, across the domain of psychology, the measurement of emotion is problematic. Subjective measures can be augmented by objective measures of autonomic nervous system (ANS) activity. ANS is a system that is responsible for regulating organ function, contains the sympathetic (activation) and parasympathetic (relaxation) branches. Measures of ANS activity include electrodermal, cardiovascular, and respiratory response, all of which are widely used and strongly correlate with positive and negative emotions (Kreibig, 2010). Each of these measures reflect either sympathetic activity (e.g., electrodermal), parasympathetic activity (e.g., respiration rate), or both (e.g., cardiovascular response). The so-called 'Induction methods' of emotions (e.g., film/music) (Kučera & Haviger, 2012) have a much more reliable influence on ANS measures than other means of emotional induction methods (e.g., slides of pictures), highlighting the autonomic specificity hypothesis – where specific subjective emotions evoke specific ANS response (Cacioppo, Berntson, Larsen, Poehlmann, & Ito, 2000). For example, negative emotions was correlated with an increase in sympathetic nervous system activation (McCraty, Atkinson, Tiller, Rein, & Watkins, 1995).

The electrophysiological effects of sound and music stimulation has been reported. Listening to unpleasant mechanical sounds was found to significantly lower HR compared to pleasant bird sounds (Yanagihashi, Ohira, Kimura, & Fujiwara, 1997). A decrease in HR has been associated with anger (Marci, Glick, Loh, & Dougherty, 2007), and is associated with a high arousal response (Christie & Friedman, 2004; Dougherty et al., 2004). BVP amplitude, which increases with calm states and reduces with stressed or aroused states (Haag, Goronzy, Schaich, & Williams, 2004), was reported to be greatest while listening to neutral music and lowest for unpleasant music, and was negatively correlated with pleasure ratings (Salimpoor, Benovoy, Longo, Cooperstock, & Zatorre, 2009). Music that elicited negative emotion (*fear*) significantly increased SC (Krumhansl, 1997) compared to listening to *happy* music. Interestingly, respiration rate measures increase while listening to both *happy* and *fear*-inducing music, but not to sad music (Etzel, Johnsen, Dickerson, Tranel, & Adolphs, 2006). This latter finding can be explained by the decrease of respiration rate that has been linked to the decrease of arousal state (Iwanaga & Tsukamoto, 1997).

Research into ANS response while consuming food and beverages is limited. To date, studies have investigated ANS response to the five basic tastant solutions (Rousmans, Robin, Dittmar, & Vernet-Maury, 2000), and related to sensory perceptions of food varying in liking (de Wijk, Kooijman, Verhoeven, Holthuysen, & de Graaf, 2012). ANS response has also been used to predict the liking of breakfast drinks (de Wijk, He, Mensink, Verhoeven, & de Graaf, 2014), and fruit juices (Danner, Haindl, Joechl, & Duerrschmid, 2014). Rousmans *et al*. (2000) showed that sweet solutions elicited weaker autonomic responses (SC, BVP, HR, and Skin Temperature), while bitter solutions evoked stronger autonomic responses. The changes in autonomic response was probably due to the innate acceptance of *sweetness* and rejection of *bitterness* (Steiner, 1977, 1979). Autonomic responses can also predict likings of beverages (e.g., breakfast drinks) (de Wijk et al., 2014). Liked foods increased finger skin temperature and HR, and significantly decreased skin conductance (SC) compared to disliked foods (de Wijk et al., 2012). Similarly Danner et al. (2014) found SC and liking of food to be negatively correlated. Skin temperature and heart rate were on the other hand positively correlated with food liking (de Wijk et al. 2014).

The crossmodal interactions between audition (e.g., music) and food (e.g., flavour) has been researched in the past decades. In one study, participants were provided with music varying in liking (disliked, neutral, and liked music) and asked to provide ratings of taste and emotional responses to chocolate gelati (Kantono et al., 2016). It was shown that the positive emotions evoked by liked music was correlated with sweetness, while negative emotions evoked by disliked music was correlated with bitterness. However, in their study participants with high social desirability and (or) with alexithymia were not identified and excluded. High social desirability was also shown as a potential issue in subjective emotion ratings, as they will be reluctant to report negative emotions in a self-reported test (Paulhus & John, 1998) and participants with alexithymia are only able to react to emotional stimuli but having difficulties in reporting it (Lane, Ahern, Schwartz, & Kaszniak, 1997). Given the issues that arise when using self-reported emotion ratings, other more objective approaches to measuring emotion such as peripheral physiology (ANS) (i.e., cardiovascular, respiratory, and electrodermal response) can enhance internal validity and better represent the relationship between emotion and food perception.

This research aimed to explore how music influences objective (i.e. electrophysiological) and subjective measures of emotion in explaining sensory perception of chocolate gelati. We hypothesise that electrophysiological responses and self-report measures of emotions will positively correlate with specific emotions and would be a good predictor in the explaining changes in sensory perceptions. This will be the first research carried out to understand the underlying associations between subjective sensory flavour responses over time, emotional ratings, and objective ANS responses.

Materials and Methods

Ethics Statement

Ethical approval was granted by The Auckland University of Technology Ethics Committee.

Participants

Ninety panellists (35 males, 55 females) aged between 21 and 52 years old (Mean = 22.3; SD = 8.1) participated in this study. Selection of participants and their recruitment were carried out similar to that reported by Kantono et al. (2016).

Music Selection

14 music genres were selected in this study, each represented by a single songs downloaded from iTunes and was equalised to 70 dB SPL. Participants were then asked their liking of 14 songs using an unstructured line scale. More details can be found in Kantono et al. (2016) and Kantono et al. (2015).

Gelati Preparation and Presentation

The bittersweet gelato samples were using an ice cream maker. Gelato samples were then prepared into containers, stored, and tempered prior to serving. Samples are randomised and counter-balanced. Detailed procedure can be found in Kantono et al., (2016).

Temporal Dominance of Sensations

In this study, the Temporal Dominance of Sensation (TDS) method was modified according to (Jager et al., 2014). Specifically, the intensity scales typically deployed in TDS were not included in this study but were instead replaced with buttons corresponding to the presence of sensory attributes (e.g. sweet, bitter, cocoa, milky, creamy, vanilla, roasted). TDS data was subsequently binary coded across time (0 for unchosen attributes and 1 for chosen attributes). During the testing when one button representing a single sensory attribute was selected, the other buttons would become automatically deselected in order to adhere to the concept of dominance. The sensory attributes in this study followed Kantono et al., (2016) (sweetness, bitterness, cocoaness, milkiness, and creaminess) with the addition of *vanilla* and *roasted* flavour attributes based on the fifteen sensory attributes of ice cream (Guinard & Mazzucchelli, 1999; Mazzucchelli & Guinard, 1999). In addition, by Pineau et al. (2012) recommendations for TDS were also implemented.

The TDS procedure in this study adapted the protocol reported by Jager et al. (2014) to train participants with no experience in sensory analysis. Similar training approach by Kantono et al., (2016) was used where participants were provided: 1) demonstration videos, 2) familiarisation of dummy trial for TDS. Panel leaders were also instructed to actively ask participants whether they understood the procedure. Figure 1 presents the TDS assessment screen.

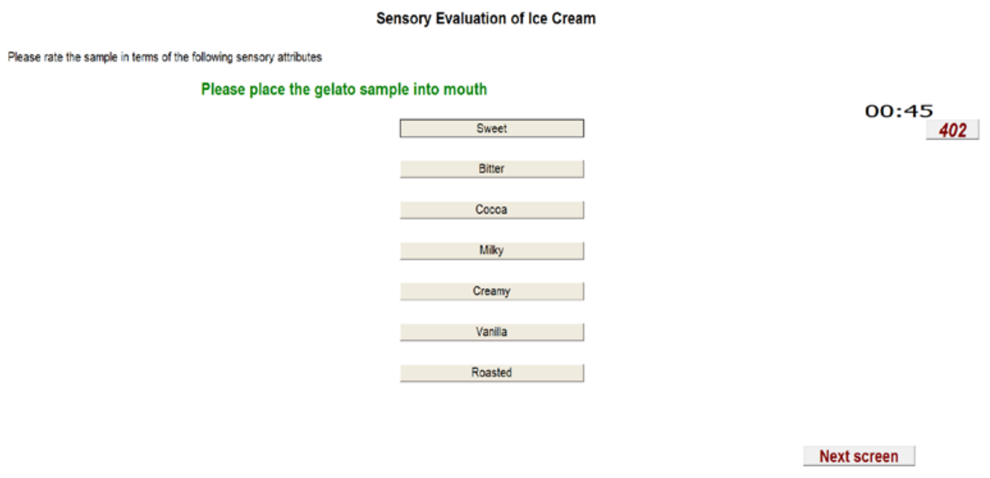


Figure 30. Representation of the TDS screen.

Emotional response of music

Measurement of emotional responses to music was carried out according to Kantono et al. (2016) using unstructured intensity line scales. In summary, the previous nine emotions were used and identified (Posner, Russell, & Peterson, 2005). 10 emotions (*Amusement*, *Happiness*, *Enjoyment*, *Anger*, *Contempt*, *Disgust*, *Love*, *Disappointment*, and *Satisfaction*) were measured. Emotion attributes along with their descriptions and examples (Table 10) were provided to the participants prior to testing ensure they fully understood the meaning of each emotional attribute. Measures of emotional response was done in between TDS sessions. This should measure the emotions of food sample influenced by music. Temporal measures of emotions was considered in this study, however it was shown to be too difficult for consumers during our pilot trial.

Table 10. Emotion attributes, classification, and description used in the current study

Sensory attributes	Valence	Description
Anger	-	Annoyance, displeasure, hostility
Contempt	-	Feeling of negative-ness, mean, vile, dishonoured
Disappointment	-	Sadness due to lack of fulfilment of expectations
Amusement	+	Enjoyment from an entertainment, or surrounding context and environment
Disgust	+	Disapproval of something unpleasant and offensive
Happiness	+	Feeling of pleasure and contentment
Enjoyment	+	Positive pleasure of having something good
Love	+	Intense affection
Satisfaction	o	Peaceful, happiness, calm, feeling when an outcome is above expectations

Physiological measures

The physiological measures in this study follows the protocol proposed by Medvedev et al., (2015). NeXus 10 and BioTrance software (Mind Media, Netherlands) were used for all ANS measures. Electrodes (gelled Ag/AgCl) were used to measure electrophysiological readings from participants. Peak-to-peak distance of heart beats was recorded as heart rate, skin conductance was measured from the non-dominant middle finger. In addition, respiration rate was recorded using a transducer belt generating electrical signal based on the tension.

Trial started with the recording of a ten minute baseline. Participants were encouraged to sit in a relaxed comfortable position, straight, and not to move their left (non-dominant) hand throughout the duration of the experiment. In the second trial session, a headset (Series HD 518, Sennheiser Electronics GmbH and Co. KG) was provided and participants listened their selected music varying in liking. All conditions were randomised and counter balanced between participants and trials. Finally, the same physiological parameters were recorded. However in this final recording session, participants consumed chocolate gelato (8.0 ± 0.4 g) under silent and three music conditions which lasted 45 seconds for each condition.

Experimental procedure

The measurements in this study were separated into four major sections using three different sensory booths due to its complexity: 1) Determination of participants' music genre liking, 2) Recording participants' electrophysiology ratings (baseline and with food sample), 3) TDS measurements, and 4) Subjective emotion ratings. Firstly, participants provided liking ratings for 14 different music genre. The least and most liked music genre were selected as disliked and liked music in this study respectively. In addition, a neutral music was also selected based on participants' ratings (near to 5 on 0-10 scale). They were then informed to move to the next booth where electrophysiology measurements were setup measuring RESP, SC, BVP, and HR. For the first 10 minutes participants' baseline were measured. Participants were then provided with the food sample and the music stimuli (liked, neutral, and disliked). Participants were asked to consume each sample prior starting each music. Each music lasted for 45 seconds. After electrophysiology measurement was complete, participants were then invited to move to the third sensory booth where TDS and emotion measurement were setup. Participants were again provided with the food and music stimuli. TDS trial lasted for 45s measuring temporal taste and flavour. After each food-music TDS trials, participants subjective rated their emotions using intensity scale. Prior to TDS trial, participants were actively asked by the panel leader whether they have any questions on TDS procedures, and the definition for each sensory and emotion attributes. When participants are in doubt with the methodology and/or definition of each attributes, the panel leader may invite him/her to the fourth sensory booth where a dummy TDS trial was setup with a brief introductory video. The trial lasted for 90 minutes for each participants.

Data analysis

TDS curves

The dominance rate of each attributes were plotted overtime. FIZZ software (v. 2.46b) plotted all spline-based smoothed TDS curves (Lenfant, Loret, Pineau, Hartmann, & Martin, 2009). Aggregation of TDS data was carried out and chance, significance level were calculated (Pineau et al., 2009). TDS time was presented as standardized time (Vidal et al., 2016) to better understand perception with higher agreement. The data was converted to percentage (0% to 100%).

Emotional response to music

One way repeated measures ANOVA (RM-ANOVA) (α=.05) was applied to explore significant differences in emotional responses of different music varying with liking. Tukey's multiple comparison tests were carried out for analyses that reached statistical significance.

Electrophysiology measures

Average values of physiological parameter measured (i.e. RESP, SC, BVP, and HR) were extracted. The baseline or silent condition was taken as reference. Based on the results of Medvedev, Shepherd, and Hautus (2015), the percentage of change from the baseline was calculated according to the formula to analyse the data where the percentage change is measured by subtracting the raw value to the mean baseline value divided by the mean baseline value.

RM-ANOVA was applied to the modified data with music condition and judge effect as factors taken into account. Tukey post-hoc comparison was applied when significance was observed.

Partial Least Square Regression (PLSR) and Path Modelling (PLS-PM)

PLSR was performed using PLS (Unscrambler, CAMO ASA, Oslo, Norway). PLSR are widely used to illustrate relationships between two datasets, in this case sensory and physiological measures. Contributions of each factors was then drawn using regression coefficients.

PLS-PM was performed with the XLSTAT PLSPM module of the XLSTAT software (Addinsoft, Paris). PLS-PM is mainly used to understand cause-effect models (i.e. S-R model in psychology). As used in this study, PLS-PM summarized the relationships between physiological measurements, emotional ratings, and sensory attributes. PLS-PM was used in this study due to its advantages: 1) construct latent models with non-normality, 2) suitable for small to medium samples, and 3) multicollinearity In order to check whether the model was reliable, Goodness of Fit (GoF) statistic, Cronbach's α, and Dillon-Goldstein's rho were also determined for each manifest variable. Additionally, the R^2 value of the latent variable was also calculated. A value greater than 0.7 for all three statistics indicates sufficient reliability (Nunnally, Bernstein, & Berge, 1967).

Results

Emotion Responses

Table 11. Emotion ratings after consumption of gelati while litening to music varying in liking. * represents significance observed for the emotion terms across four sound conditions. a,b,c,d denote mean values of ratings with different superscripts indicating significance ($p < 0.05$).

	Music condition				
Emotions	**Silent**	**Liked**	**Neutral**	**Disliked**	**F-value**
Anger $^{-}$	0.643	1.012	0.653	0.849	2.0
Contempt $^{-}$	1.748	1.873	1.729	2.154	0.7
Disappointment	0.759^{b}	0.659^{b}	0.634^{b}	2.096^{a}	8.0*
Disgust	0.954^{b}	0.851^{b}	0.832^{b}	4.979^{a}	40.2*
Amusement $^{-}$	3.169	3.585	3.213	3.966	1.2
Enjoyment	2.057^{d}	6.729^{a}	5.954^{b}	4.232^{c}	10.4*
Happiness	3.280^{d}	7.792^{a}	5.252^{b}	4.158^{c}	10.0*
Love	3.143^{d}	5.718^{a}	4.902^{b}	4.180^{c}	10.8*
Satisfaction	1.362^{d}	6.844^{a}	5.641^{a}	4.766^{c}	12.6*

Table 11 showed that positive emotions (*enjoyment*, *happiness*, *love*, and *satisfaction*) were rated significantly higher while listening to liked music compared to silent, neutral music, and disliked music conditions. Negative emotions such as *disappointment* and *disgust* were significantly higher under disliked music condition compared to other conditions (silent, neutral, and liked music). High arousal negative emotions (*anger*, and *contempt*), and positive emotion (*amusement*) showed no significant differences.

Temporal Dominance of Sensations

Figure 31 displays smoothed TDS curves using the spline equation for all samples. In our study, the calculated chance level and significance level was found to be between 15% and 25% respectively. Therefore, attributes below 25% significance level in our study that were not considered dominant will not discussed further.

During the silent condition, sweetness was the first dominant attribute, subsequently decreasing from a maximum dominance rate of 47% between 0 - 10% standardized time (ST). Creaminess was observed after 4% ST and increased between 15 - 19% ST, reaching a maximum dominance rate of 42% at 15% ST. Creaminess later decreased until 28% ST. Finally, bitterness was dominant from 57% ST until the end of the evaluation reaching a maximum dominance rate of 36% at 87% ST. For liked music, sweetness was the main dominant attribute selected by panellists. Indeed, a longer duration sweetness was observed from 0 - 23% ST, then from 40 -100% ST with a maximum dominance rate of 55% at 0% ST. Bitterness increased significantly at the late period of mastication (from 80 – 100% ST) reaching a maximum dominance rate of 40% at 0% ST at 92% ST. When a neutral song was played, cocoa showed higher dominance rate and longer duration of time from 0 - 24% ST, reaching a maximum dominance rate of 40% at 9% ST and 11% ST. Milkiness was significantly dominant between 30 - 40% ST, reaching 44% dominance rate at 32% ST. Finally, bitterness was dominant from 60 – 100 % of ST, with a maximum dominance rate of 36% at 100% ST. Finally, in the disliked music condition, sweetness was perceived as a dominant attribute at several points of evaluation. It was significant between 0 – 24% ST, with a maximum dominance rate of 47% at 2% ST. It was again dominant between 42 - 60% ST and 65 - 80% ST. Creaminess was dominant between 6 - 17% ST reaching a dominance rate of 37% at 17% ST. Finally, bitterness was significantly perceived by the panel from 60 - 100 % ST, reaching a maximum dominance rate of 42% at 100% ST.

Figure 31. Panel dominance rate (%) of the 7 sensory attributes presented in TDS sessions in terms of standardized time (%). The four music conditions are: Silent condition (or reference) (a), neutral music condition (b), liked music condition (c), and disliked (d).

Electrophysiological responses

One-way RM-ANOVA was significant for the effect of music on SC ($F_{(2,119)} = 141.291$, $p < 0.01$), BVP ($F_{(2,119)} = 25073.053$, $p < 0.01$), and HR ($F_{(2,119)} = 24.01$, $p < 0.01$) measures only (Figure 32). No significance was observed for the RESP measures ($F_{(2,119)} = 0.018$, $p > 0.05$). In terms of cardiovascular measures, HR measure of liked music was significantly the highest. BVP resulted in the highest changes while listening to neutral music, followed by liked, and disliked music. SC was the highest while listening to disliked music that was followed by neutral, and liked music subsequently. However, RESP showed no significance in this study.

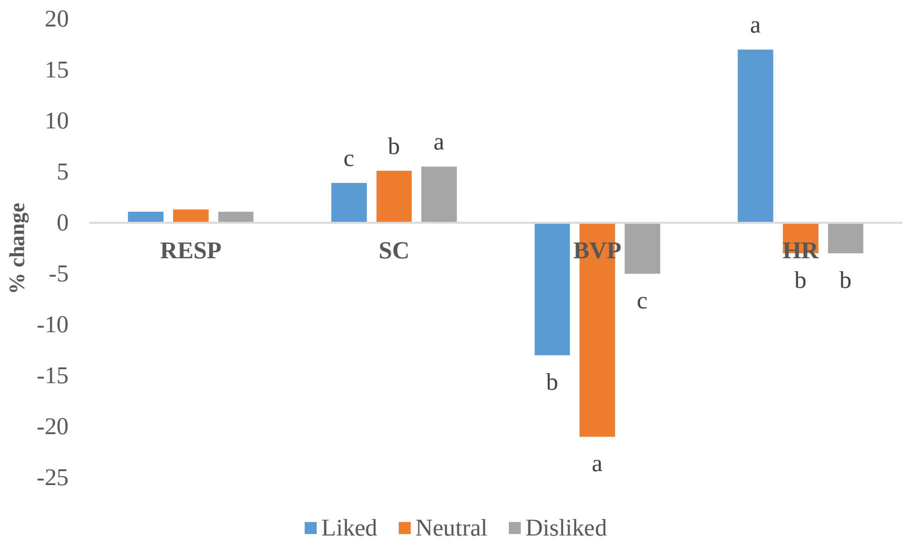


Figure 32. Physiological measure values using Respiratory Rate (RESP), Skin Conductance (SC), Blood Volume Pulse (BVP), and Heart Rate (HR). Values were calculated based on the changes in baseline (silent condition) compared to three music conditions (liked, neutral, and disliked). a,b,c,d: changes in physiological measure readings with different superscripts indicating significance (p < 0.05). Error bars represents standard error.

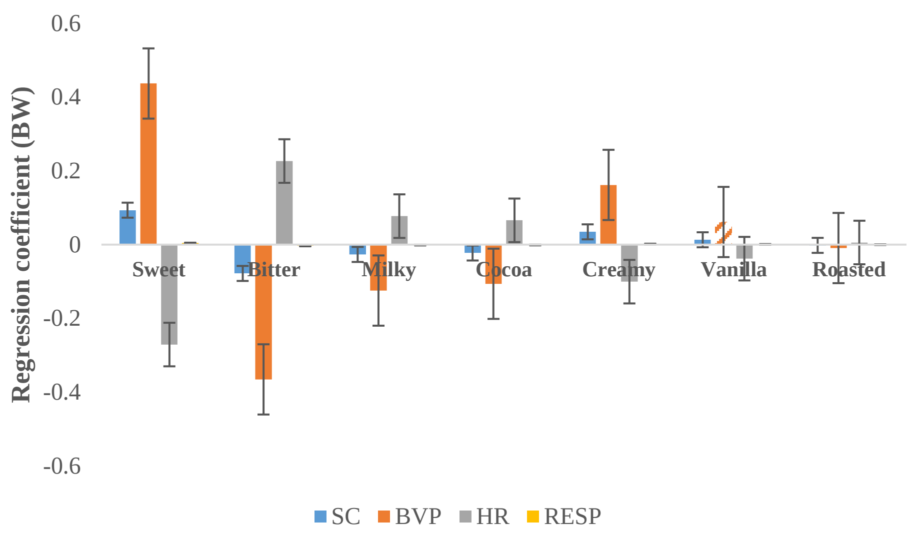
Relationship between electrophysiology measures, sensory perception, emotion response

Figure 33 illustrates the relationship between electrophysiology measures and sensory perception using PLS regression coefficient values.

In terms of sensory attribute cardiovascular measures such as HR were found to be positively associated with sweetness, and to a lesser extent with milkiness, and cocoaness sensations. In contrast, it was correlated negatively with bitterness and somewhat correlated with creaminess and vanilla sensation. Electrodermal (SC) response and BVP shows to be positively associated with bitterness and to some degree with creaminess and vanilla, while was negatively associated with sweetness and to some degree of milkiness and cocoaness sensations. Respiratory (RESP) measure were not correlated to any sensory and emotion attribute.

ANS response shows to correlate with positive emotions (*amusement, enjoyment, happiness, love, and satisfaction*) and one negative emotion (*disgust*). Particularly, HR shows positive correlation with positive emotions (*amusement, enjoyment, happiness, love, and satisfaction*) and to some lesser degree to negative emotion (*anger, and disgust*). BVP shows positive correlation with disgust, and amusement, and shares negative correlation with satisfaction and disappointment. SC was shown to positively correlate with disgust and amusement, while having negative correlation with enjoyment, happiness, love, and satisfaction.

a)



b)

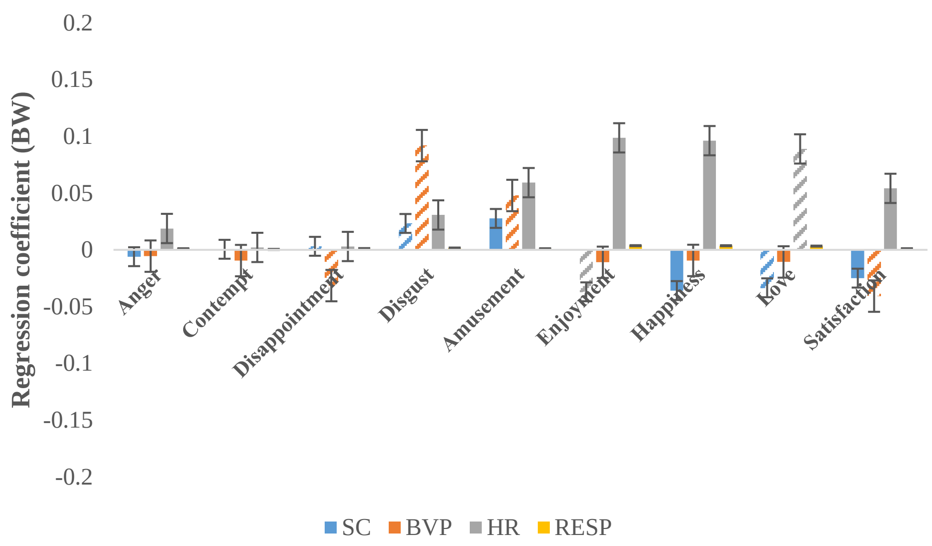


Figure 33. Calculated regression coefficient using PLSR between: a) physiological measures and sensory measures, b) physiological measures and emotion measures. Filled bars indicates significant regression coefficient (BW).

Overall relationship between electrophysiological and emotion measures, and sensory perception

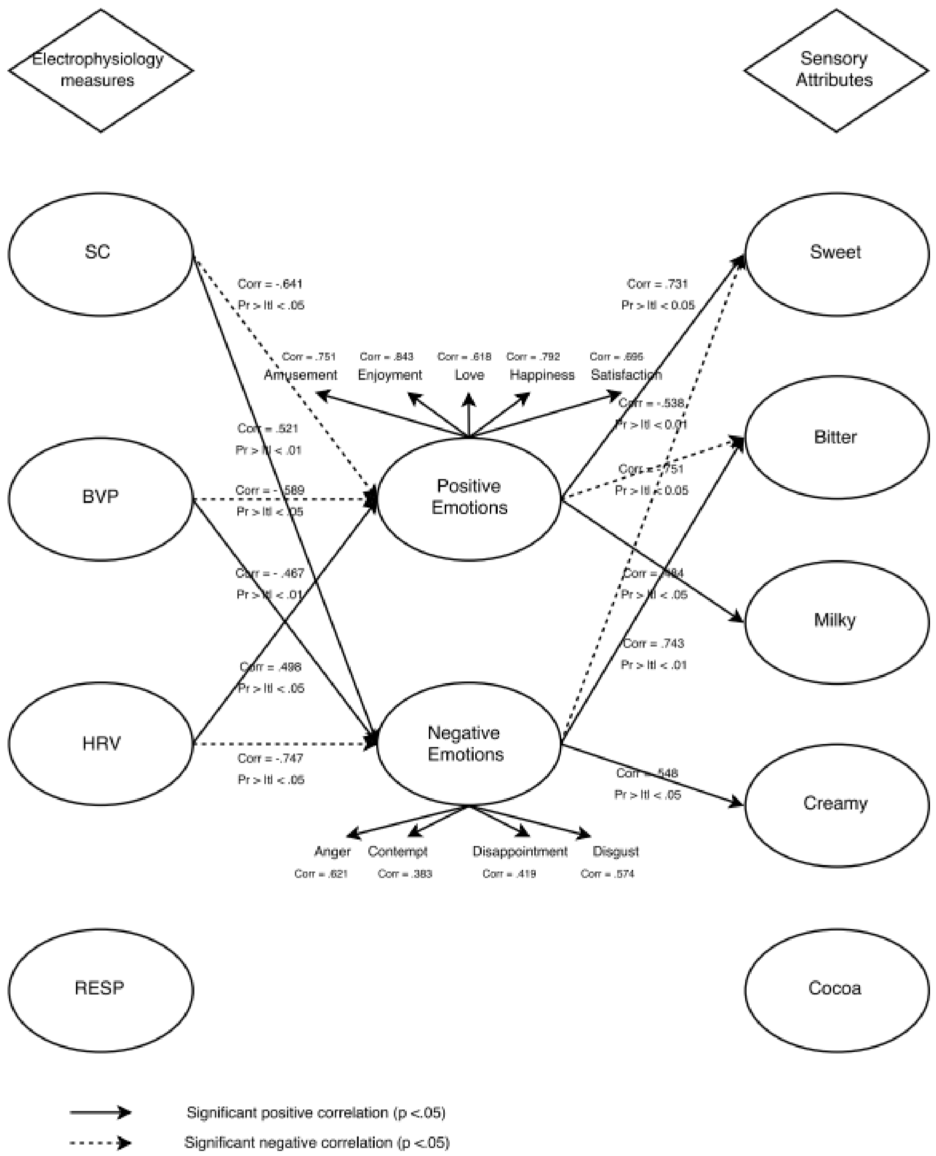


Figure 34. PLS-PM showing the significant correlations between physiological measures, self-rated emotion, and sensory perception. Significant correlations are indicated by the lines added. Absence of lines between the latent variables indicates no significant correlation.

PLS-PM in this study explained the relationships between physiological changes, subjective rated emotion, and sensory perceptions (Figure 5) well. Cronbach's α, Dillon-Goldstein's rho, and R^2 value of each variable were > 0.7, indicating overall correctness and reliability of measured variable (Nunnally et al., 1967). GoF measured value was similar to the GoF of bootstrapping model (GoF = .583). The model constructed showed that physiological measures such as SC, BVP, and HR could be linked to the subjective measures of emotions by participants. However, RESP showed a no significant correlations with these self-rated emotions.

Negative emotions were positively significant correlated with SC, and BVP measures, while significantly negatively correlated with HR measure. Positive emotions were positively significant correlated with HR measure, while being significantly negatively correlated with SC and BVP measures.

Negative emotions showed a significant positive correlation for bitterness and creaminess, while showing a significant negative correlation for sweetness. Positive emotions showed a significant positive correlation for sweetness and milkiness, while showing a negative correlation for bitterness.

Discussion

Electrophysiological measures explains emotion and sensory changes while listening to music

This study is the first study that utilises psychophysiology technique to quantify emotional changes in participants within the area of crossmodal correspondence between sounds and flavours. Subjective emotion ratings may induce introspection illusion, which may influences participants in evaluating their self-rated emotions (either to extreme levels or least ratings).

The use of electrophysiology measures such as cardiovascular and respiratory measures will further strengthen the mood mechanism proposed by Kantono et al. (2016) which used subjective emotion ratings to understand the influence of emotions evoked when eating while listening to music.

Heart Rate (HR) measures of liked music was the highest, followed by neutral, and disliked music. Yanagihashi et al. (1997) demonstrated that listening to sounds varying in pleasantness affects heart rate readings particularly the High-Frequency component (HF%). Listening to unpleasant mechanical sounds had the lowest HF% value and was significantly different compared to the pleasant bird twitter, and music synthesizer sounds. In contrast, listening to pleasant bird twitter sound evoked the highest HF% value that was significantly different compared to music synthesizer, and mechanical sounds. The authors proposed that listening to mechanical sounds inhibited the para-sympathetic nervous system and promoted an unpleasant feeling of alertness.

Blood Volume Pulse (BVP) resulted in the highest changes while listening to neutral music, followed by liked, and disliked music. Salimpoor et al. (2009). Participants in their study were provided a few music genres and self-selected their most liked (high pleasure) and most disliked (low pleasure) music. The BVP amplitude in neutral music was the highest, followed by small changes of low pleasure and high pleasure music. The authors explained that the changes were due to changes in arousal based on their electrophysiological indicators (i.e. HR).

Skin Conductance (SC) was highest while listening to disliked music, followed by neutral, and liked music. These results are consistent with Krumhansl (1997) who investigated the correlation between music emotions and electrodermal response. In this study, two musical excerpts that represented *sad*, *fear*, and *happy* emotions were selected. Highest changes in electrodermal SC were consistent with results from our study while listening to *sad* music. It was concluded that listening to disliked music evoked negative emotions which correlates to the electrodermal system.

Etzel et al. (2006) had shown that increase of RESP has been correlated with positive emotions (*happiness*) while decrease in RESP measures has been correlated with negative emotions (*fear and sadness*) while listening to musical excerpts. This differs from the findings presented here; surprisingly, no differences were found in Respiration Rate (RESP). A possible explanation for this might be that their study demonstrated electrophysiology findings of musical excerpts to evoke particularly a singular emotion (i.e *happiness, fear*, or *sadness*). Participants in this study listened music varying in liking which was self-selected. This means that the selected music may carry personal meaning and some degree of familiarly to the participants which may influence emotions evoked by the music (Blood & Zatorre, 2001). In addition, our study showed that music evoked to some degree multiple emotional responses. In an example, listening to liked music does not only evokes *happiness* as high valence, high arousal emotion but also *enjoyment* a high valence, low arousal emotion. Hence, the emotions evoked by self-selected music in this study does not differentiate arousal account which may explain the lack of significance in RESP, as RESP measures has been linked as an indicator for the parasympathetic nervous system (Pomeranz et al., 1985), which can be linked to the sedative/relaxing effects of music (Iwanaga & Tsukamoto, 1997).

Sweetness was positively correlated with SC and BVP measures, but negatively associated with HR measure. In contrast, an inverse relationship was observed for bitterness. In Rousmans et al. (2000) study, participants were provided with sweet, salty, sour and bitter stimuli solutions. Cardiovascular and electrodermal ANS parameters were measured. Their results demonstrated that sweetness was correlated to weaker ANS response, while innate-rejected bitter taste inducing the stronger ANS responses. According to the authors, a possible explanation for this might be due to the innate organic acceptance of sweetness that decreases ANS responses. In contrast, bitterness reflects toxic/harmful foods and induces bitterness which increases ANS responses in individuals (Steiner, 1977, 1979).

ANS responses using electrophysiology measurements were used to predict sensory likings of food (de Wijk et al., 2012). de Wijk et al. (2012) investigated the relationship between ANS responses (SC, HR, and ST) with food varying in liking. Liked food increased finger skin temperature (ST) and HR, and significantly decreased SC. Similarly, significant negative correlation between SC and food liking was also demonstrated (Danner et al., 2014), and a significant positive correlation between HR and food liking (de Wijk et al., 2014). Although food liking wasn’t measured in this study, we propose that the temporal sensory changes of milkiness and cocoaness in this study maybe partially explained as both sensory attributes were drivers of liking in chocolates (de Melo, Bolini, & Efraim, 2009). The changes were in line with our results where both drivers of liking (milkiness and cocoaness) were negatively correlated with SC and BVP measures, and positively associated with HR.

Interestingly, SC and BVP measures was shown to positively correlate with creaminess, and negatively with HR in our study. Platte et al. (2013), healthy and mild sub-clinically depressed participants viewing a sad movie, rated higher intensities of fat taste for 6% and 10% milk fat dairy solutions compared to watching neutral and happy movies. Creaminess has been associated with negative emotions of *fear* (Krumhansl, 1997), *displeasure* (Salimpoor et al., 2009), and *anger* (Marci et al., 2007) for increase of SC and BVP measures, and decrease of HR measures respectively.

Emotions evoked during consumption while listening to music

Music has been widely used in the psychology as an affect modulator evoking positive emotions (Eifert et al., 1988), and negative emotions (*bad feeling*, and *unpleasantness*) which influences consumers' attitudes towards a product (Blair & Shimp, 1992). Brown et al. (2004) reported that listening to liked music activated the nucleus accumbens, orbitofrontal cortex, and ventromedial prefrontal cortex all linked in processing of positive emotions. Pereira et al. (2011) showed listening to disliked music regulates activity in limbic and reward system regions. Emotions with high levels of arousal (e.g., *anger*, *contempt*, and *amusement*) showed no significant differences during consumption while listening to music varying in liking. Similar findings was found by Desmet and Schifferstein (2008), they argued that high arousal states were seen as inhibiting food consumption (Macht, 2008).

Influence of music on temporal flavour perception

In the silent (reference) condition, bittersweet chocolate gelato was perceived to be sweet and creamy, and bitter at the end of the mastication period. TDS profile in our study for the control condition was similar to the chocolate dairy dessert done by Morais et al., 2014, where the dominant attributes of sweetness and creaminess evolved in the early mastication period, while bitterness evolved at the end of mastication.

Listening to liked music resulted in longer dominance of sweetness and shorter dominance of bitterness sensations. In contrast, listening to disliked music showed longer dominance in bitterness and shorter dominance in sweetness. This result was similar to Kantono et al. (2016), who had established that music influenced temporal taste perception of bittersweet chocolate gelati. Positive emotions evoked by liked music increases the duration of sweetness dominance while disliked music evoked negative emotions, which increases the duration of bitterness dominance.

Neutral music was found to increase temporal cocoaness, and milkiness dominance sensations. Listening to neutral music was found to increase the pleasantness of chocolate gelati (Kantono et al., 2015). In their study, they speculated that the neutral music played may have been ignored which increases cognitive capacity for food evaluation (Madsen, 1987). This may explain the longer durations of cocoaness and milkiness attributes in this study, whereby panellists were able to free-up cognitive resources to focus directly upon the gelato flavours.

Disliked music evoked creaminess in the early mastication period and prolonged the dominance bitterness. Listening to disliked music evoked negative emotions, and may have acted as a mild stressor. Torres and Nowson (2007) reported that consumers exposed to stressful situations may crave for high-fat food. This may explain the increase of creaminess perception noted in our data, which is linked with fat perception in ice cream (Guinard et al., 1997).

Relationships between electrophysiology, emotion, and sensory perception

In our study, negative emotions were positively associated with SC and BVP measures. Salimpoor et al. (2009) have shown that an increase in BVP measure was negatively correlated with pleasure. Increase in BVP measures can be due to the overall increase in autonomic activation (McCraty et al., 1995). SC ratings increased when listening to music that evoked negative emotions. This can be explained by the effect of arousal towards top-down regulations (Khalfa, Isabelle, Jean-Pierre, & Manon, 2002) in which music activates sympathetic nervous system (amygdala, hypothalamus, and cortical structures, orbito-frontal cortex, and temporal lobes) (Critchley, Mathias, & Dolan, 2001).

On the other hand, negative emotions were found to be negatively associated with HR measure. Marci et al. (2007) showed that negative emotions (*anger*, and *sadness*) was evoked using emotion scripts their HR measure decreases. They explained that negative emotions (*anger*, *disgust*, *fear*, and *sadness*) generated high level of arousal, correlated with sympathetic activity increase and parasympathetic activity decrease (Christie & Friedman, 2004) and increases in left orbitofrontal cortex activities (Dougherty et al., 2004).

Negative emotions showed positive correlation for bitterness, while positive emotions showed positive correlation for sweetness. Using music to evoke emotions, Kantono et al. (2016) showed a positive association between positive emotions (*satisfaction*, *happiness*, and *amusement*) and sweetness sensation, and negative emotions (*contempt*, *disappointment*, and *disgust*) with bitterness sensation. A related study by Jager et al. (2014) with different chocolates (mint, fruit, and dark chocolate), also found that negative emotions (*bored*, *aggressive*, and *guilty*) were associated with dryness, and bitterness sensation of the dark chocolates. Fruity chocolates on the other hand were associated with positive emotions such as *happiness*, *loving*, and *interested* and sweetness sensation.

Interestingly, positive emotions was also significantly correlated with milkiness; while negative emotions was also shown significantly correlated with creaminess. In ice cream, creaminess has been related with the fattiness (Guinard et al., 1997). Torres and Nowson (2007) demonstrated that consumers would consume more fatty food under stressful conditions. Platte et al. (2013) further showed that a negatively induced cue (sad movie) increased fat ratings of milk-cream mix compared to a positively induced cue (happy movie) at lower concentrations.

This study demonstrated the influence of positive emotions evoked by neutral/liked music increased the perception of milkiness in ice cream sample. Positive mood state have been shown to decrease taste threshold according to Heath, Melichar, Nutt, and Donaldson (2006). When serotonin was delivered to participants to induce a positive mood state, their sweetness threshold for the sucrose solution decreased.

A negative correlation with sweetness was found with negative emotions. Positive emotions were negatively correlated with bitterness. Kantono et al. (2016) showed positive emotions (*satisfaction*, *happiness*, and *amusement*) induced by liked music decreased bitterness of bittersweet chocolate ice cream. Listening to disliked music, evoked negative emotions (*contempt*, *disappointment*, and *disgust*) and decreased sweetness perception. Disliked music may have acted as a mild stressor in this study. Studies have demonstrated that participant's perception of bitterness of saccharin solution increase with exposure to mild stressor (Dess & Edelheit, 1998), and a less intense sweet perception of sucrose solution (Al'absi et al., 2012).

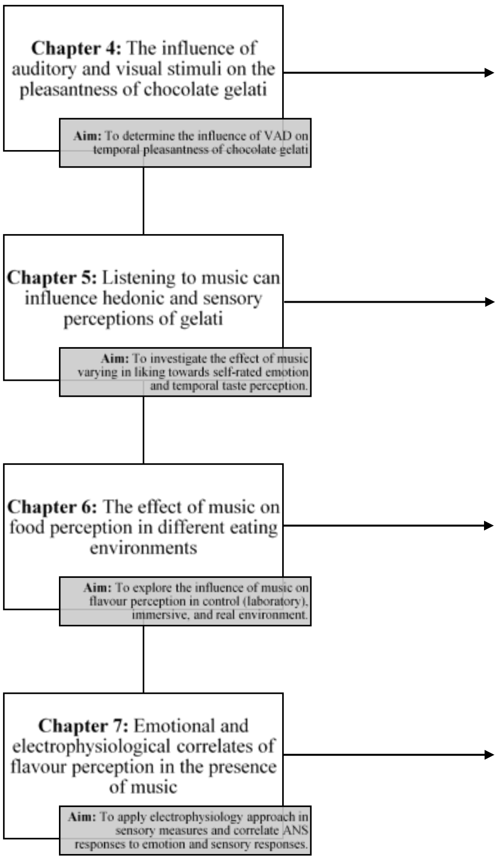
Conclusion

This study explored electrophysiological and subjective emotional measures to provide an understanding on how music influences gelato perception. PLSR and PLS-PM analysis demonstrated a clear correlative relationship between electrophysiological measure, subjective emotion measure, and sensory perception. In this study gelato flavour was correlated with emotions. Electrodermal and cardiovascular measures was important variable predicting sensory attributes. Increase of SC and BVP were associated with sweetness and creaminess and its decrease were associated with bitterness, milkiness, and cocoaness. While HR showed an inverse relationship. Positive emotions *(amusement, enjoyment, love, happiness,* and *satisfaction)* evoked by liked music was correlated with sweetness. Neutral music evoked the same positive emotions to liked music but to a lesser extent and was correlated to milkiness. Negative emotions *(anger, contempt, disappointment,* and *disgust)* evoked by disliked music were correlated with bitterness and creaminess. Cardiography measures (BVP, and HR) and electrodermal response (SC) were accurately associated with subjective measures of emotions. BVP and SC was positively correlated with subjective negative emotions (*anger, contempt, disappointment,* and *disgust*) and negatively correlated with positive emotions (*amusement, enjoyment, love, happiness,* and *satisfaction*) rating. HR was both correlated with positive emotions (positive association) and negative emotions (negative association). RESP measure in this study did not reach significance as it reflects the parasympathetic nervous system associated with the relaxation effect of music.

As emotion is a complex measure, it is highly recommended that future studies administer a more complex emotion scale such as a consumption emotion descriptors scale (Richins, 1997) that can capture a higher resolution of emotions evoked by a stimuli. Other electrophysiological measures of the brain (i.e. electroencephalography and fMRI) may be utilised further understand the changes in the brain reward system linked to emotion, and to observe its' correlational effect towards flavour perception while listening to music in the context of food consumption.

Chapter 8. General Discussion

Overview



Results:

- Café sound evoked high valence, low arousal and dominance affective rating and increased temporal pleasantness
- Bar sounds evoked low valence, high arousal and dominance affective ratings that decreased temporal pleasantness.

Results:

- Listening to liked music evoked positive emotions (amusement, happiness, and satisfaction) that increased sweetness dominance and decreased bitterness dominance
- Listening to disliked music evoked negative emotions (contempt, disappointment, and disgust) that increased bitterness dominance and decreased sweetness dominance
- Emotions modulated taste perception. Positive emotions evoked sweetness and dampened bitterness. Negative emotions evoked bitterness and dampened sweetness perception.

Results:

- Cocoaness, milkiness, and sweetness were more cited. in a real environment compared to the laboratory environment with disliked, neutral and liked music.
- Sweetness, and bitterness were modulated in the real environment while listening to liked and disliked music.
- Listening to liked and disliked music consistently increased sweetness and bitterness respectively in the real environment.

Results:

- Skin Conductance and Blood Volume Pulse were positively correlated with sweetness, and creaminess.
- ANS responses correlated with subjective ratings of positive (Amusement, Enjoyment, Love, Happiness, Satisfaction) and negative (Anger, Contempt, Disappointment, Disgust) emotions.
- Listening to liked and neutral music evoked positive emotions that were positively correlated with sweetness and milkiness.
- Listening to disliked music evoked negative emotions that were positively correlated with bitterness and creaminess.

Numerous studies demonstrated the effect of auditory cues like white noise (Woods et al., 2011) or singular tones on food perception (Crisinel & Spence, 2009). Crisinel and Spence (2009) established the implicit association of pitch from musical instruments to food names. Woods et al. (2011) further investigated how loudness of noise in the background influences sensory perception of savoury and sweet food stimuli. This research will evaluate how sound affects changes in flavour of gelato with time.

Chocolate gelato was chosen in this study as it is a temporal stimulus that has been shown to evoke emotion according to Fiegel, Meullenet, Harrington, Humble, & Seo (2014). Numerous studies in food have relied on the use of self-reported emotions using questionnaire to explain emotions evoked by food such example, coffee (Bhumiratana, Adhikari, & Chambers, 2014), chocolates (Jager et al., 2014). Self-reported approaches are popular as it is easy to interpret, rich in information and practical (Paulhus & Vazire, 2007). In addition, an intrinsic approach to measure emotions was also adopted in this research by monitoring Autonomic Nervous Response (ANS) responses. Changes in ANS responses have been associated with emotions. For example, an increase in heart rate has been associated with high arousal emotion (Kreibig, 2010). This thesis investigates the influence of auditory cues varying in valence on self-reported emotion (Chapters 4, and 5) and objective (intrinsic) (Chapter 7) emotions. The auditory stimuli is also a temporal stimulus (Levitin, 2009). Hence application of temporal sensory methods are more appropriate when examining the temporal sensory perception while listening to auditory cues compared to static sensory methods (Wendin & Hall, 2001). Kantono et al. (2015) was the first to report the temporal effect of music varying in preference to the pleasantness of gelati using TI method. They found that preference influenced the pleasantness ratings of gelati. Non-preferred music decreased pleasantness ratings while preferred music increased pleasantness ratings of gelati. In addition to the TI method (Chapter 4) used in this study, other temporal methods like TDS (Chapters 5, and 7) in laboratory setting, and TCATA (Chapter 6) were used to understand how sounds influences sensory perception of chocolate gelato in different environments (laboratory, immersive, and natural eating environment).

This thesis explored the crossmodal effects between auditory cues on sensory perception of chocolate gelati. In Chapter 4, affective states (valence, arousal, dominance), and temporal pleasantness were measured to understand the underlying effect of emotions evoked by auditory cues (in this case – sounds of different environment) on pleasantness ratings of chocolate gelati. Chapter 5 further investigated the discrete positive or negative emotions evoked by music varying in liking on temporal taste perception. Chapter 6 determined the crossmodal effects of music on flavour, in different eating environments to provide ecological validity to results obtained in Chapter 5. Finally, in Chapter 7 of this thesis, the relationship between intrinsic electrophysiological measures on subjective measures of emotion, and its relationship to temporal sensory changes while listening to music varying in liking were explored.

Influence of environmental sounds and visual cues on temporal pleasantness – Chapter 4

Numerous studies investigating crossmodal effects of sounds have relied on one-point scale measurement for measuring the changes in sensory perception. For example, Fiegel et al. (2014) had used one-point intensity scale to measure the effects of four different music genres on pleasantness and flavour intensity of chocolate and bell-pepper. However, auditory cues are temporal stimuli (Levitin, 2009), and can modulate temporal valence and arousal. Grewe, Nagel, Kopiez, and Altenmüller (2007) showed that listening to “Tuba Mirum” from Mozart’s Requiem evoked “goose bumps” and “shivers” in some parts of the music, which was further correlated to increase in valence ratings. Veldhuizen, Wuister, and Kroeze (2006) used the TI method to measure pleasantness and intensity of orange lemonade syrup and quinine sulphate solutions. Their results showed that intensity response shown to last longer than pleasantness response. This demonstrated that subjective processing of intensity are at first in serial but later may be in parallel which allows the measurement of pleasantness in time series (Veldhuizen et al., 2006).

In Chapter 4 each participant rated their maximum intensity of pleasantness at different time points for the chocolate gelati while listening to different environmental sounds. By taking into account individual variances in TI data, the non-centered PC values for each sample were extracted to ‘average’ participants TI curves. ANOVA Partial Square Least Regression (APLSR) on the non-centered PC values was then carried to observe the exact time periods of increasing and decreasing temporal pleasantness measures under the different environmental conditions. In this study, listening to pleasant café sounds resulted in maximum temporal pleasantness (IMax) ratings between 11-16 seconds for all three (dark, bittersweet, milk) chocolate gelati. Conversely, listening to unpleasant bar sound decreased the maximum temporal pleasantness (IMax) ratings between 25-29 seconds for all three chocolate gelati. Results highlighted the optimum listening duration of auditory cues when measuring pleasantness.

It is widely accepted that emotions are separated into two dimensional planes of valence, and arousal according to the circumplex model of emotion (Russell, 1980). SAM (Bradley & Lang, 1994) is an emotion pictorial assessment tool utilising pictorial scales, specifically characters expressing the two dimensions of the circumplex model: Valence and Arousal, and an additional Dominance dimension. These three emotional dimensions (known as VAD) were measured in this study using intensity scaling to assess participants’ underlying emotions while eating and listening to auditory cues. The VAD dimensions provide a basis for understanding emotional processes, where valence (pleasantness) is the attractiveness (positive) or aversiveness (negative) of a stimulus and arousal (activation) is defined as the sense of organs stimulated to a point of perception indicating the increase of autonomic activities in an individual. It is however unclear until now the role of arousal in food consumption. A study done by Desmet and Schifferstein

(2008) showed that food evoked lower levels of arousal – which supports our results in terms of pleasantness. However, arousal ratings must be interpreted with caution as it a subjective measures of emotion as opposed to objective electrophysiological measures of emotion. Dominance on the other hand relates to the attentiveness of an individual towards stimulus (Bradley & Lang, 1994). Hence, if participants did not focus on the food stimulus and got distracted, this may modulate the valance of food.

Results in Chapter 4 demonstrated the effects of valence, arousal, and dominance of sounds on chocolate gelati's pleasantness ratings. Affective VAD ratings of the stimuli were recorded prior to consuming the food sample. In addition, participants provided ratings for temporal pleasantness and VAD ratings when consuming gelati with environmental sounds with and without the visual stimuli. Valence ratings with and without gelato consumption increased in the order of bar, fast food, and café sound conditions. In contrast, arousal and dominance ratings with and without gelato consumption, increased in the order of café, fast food, and bar sound conditions. Café sounds, which evoke high valence, and low arousal and dominance ratings, may evoke appetitive emotions (positive emotions) and was the least distractive. On the other hand, bar sounds, which evoked low valence, and high arousal and dominance ratings may evoke defensive emotions (negative emotions), and was the most distractive. The temporal pleasantness of gelati was highest while listening to café sound > fast-food restaurant > bar sounds. Chapter 4 supports the mood mechanism proposed by Woods et al. (2011) who proposed that listening to auditory cues may influence affect/emotion, which can further influence sensory perception. Another mechanism that can explain the increase of pleasantness while listening to the valent café sounds was proposed the "sensation transfer". Seo and Hummel (2011) demonstrated that participants who listened to pleasant sound stimulus (jazz music) rated higher pleasantness ratings of odour stimulus (coffee) compared listening to unpleasant sound (baby crying). Results of this study showed that listening to pleasant café sounds increased valence, and decreased arousal, and dominance ratings. Conversely, listening to unpleasant bar sound decreased valence, and increased arousal and dominance ratings. This effect was amplified when visual cues were presented with the auditory stimuli. Results showed that the chocolate gelati were rated to be more pleasant under audiovisual cues conditions compared to auditory cues only.

Influence of music on emotion and taste perception of chocolate gelati – Chapter 5

Musical congruency with specific food types or flavour has become an area of interest in the recent years. With the increasing popularity of Heston Blumenthal's multi-sensory dish – '*The Sound of the Sea*' (Blumenthal, 2009), numerous studies have attempted to generate soundscapes, which matched specific taste to enhance flavour of food. Carvalho, Wang, Van Ee, and Spence (2016) reported that soundscapes from sharp notes and low tones were generated to evoke bitterness taste, and high tones and legato notes soundscapes were generated to evoke sweetness based on findings by Crisinel et al. (2012). They found that listening to sweet soundscapes evoked higher intensity of sweetness rating of toffee sample, and bitter soundscapes evoked higher intensity of bitterness rating. Carvalho, Wang, van Ee, Persoone, & Spence (2016) further investigated taste perception of beer samples consumed while listening to soundscapes, and found that liked soundscapes were positively correlated with the sweetness perception of their beer sample. It is perhaps arguably <u>not</u> the genre or congruency of the soundscape or music that matters, but the *liking* and *hedonic valence* of the auditory stimulus itself which may influence the food – taste – flavour perception.

According to the mood mechanism proposed by Woods et al. (2011) specific auditory cues may evoke emotions that influence sensory judgements. Hence, the second objective (Chapter 5) was to understand how music influenced perceptions of taste and emotion at the end of consumption. Results from Chapter 5 showed that liked music evoked positive emotions (i.e. joy, happiness), which was associated with sweetness, while disliked music evoked negative emotions (i.e. anger, contempt) which was associated with bitterness. Results from Thomson, Crocker, and Marketo (2010) and Jager et al. (2014) consistently showed that sweetness was associated with positive emotion (i.e. fun, happy). However, differences in association arises from bitterness. This was probably due to hedonic tone of valence (pleasantness) being directly transferred to other stimulus (Seo & Hummel, 2011) (in this case food). Sensation transference highlights that sensory assessment of a product is not only based on the product itself, but also on secondary sensory input associated with the product (Cheskin, 1957). Thomson et al. (2010) reported that dark chocolate bitterness was associated with high arousal emotions (confident, adventurous and masculine), while Jager et al. (2014) demonstrated that bitterness of 70% and 85% dark chocolate were associated with low valence emotions (bored, aggressive, and guilty emotions). This may be due to the differences in how the emotion terms were collected, Jager et al. (2014) used emotions terms from several papers from the conventional characterisation of chocolate. Thomson et al. (2010) on the other hand, had used a small group of consumers with supervision by a panel leader. In another study, Platte, Herbert, Pauli, and Breslin (2013) used video clips to induce mood. Participants that was conditioned to positive mood rated a more acidic citric acid solution, sweeter sucrose solution, and less bitter quinine solution. In contrast, when they were conditioned to negative mood, they rated a more bitter quinine solution compared when conditioned to positive mood.

Ecological validity of the influence of music to taste and flavour perception – Chapter 6

The third research objective (Chapter 6) assessed the crossmodal effect between music, and flavour perception in three different environments (laboratory, immersive, and real eating environment) to further provide ecological validity. Previous studies have shown that hedonic ratings for foods vary with different environment and context (i.e. situations of eating – weather, time, etc.) (Meiselman, 2003). However, only Petit and Sieffermann (2007) measured frequencies of recurrent sensory terms to describe the flavour and texture of iced coffee samples in lab and real environment conditions, a product is experienced by consumers may differ depending on the environment where it is consumed. Previous studies however only focused on food acceptance in different environments. Bell, Meiselman, Pierson, and Reeve (1994) showed that consumers' perception of ethnicity and acceptability of Italian foods increased in an Italian themed restaurant. In another related study Meiselman, Johnson, Reeve, and Crouch (2000) found that food samples were significantly liked in the training restaurant environment, compared to the student hall, and laboratory setting.

In Chapter 6 of our study, participants selected their liked, neutral, and disliked music *a priori*. TCATA was employed with consumer panels to measure the temporal perception of flavour, in different environments. The underlying difference between TDS and TCATA is that TCATA does not use the term dominance but relies on the Check All That Apply (CATA) principle. Panel dominance curves were plotted expressing the citation percentage (citation rate) of panels for each sensory attribute at a given time. Multiple Factor Analysis (MFA) was utilised to demonstrate the similarity/dissimilarly between the three environments as a function of music and sensory ratings.

The TCATA method used in this study was based on the CATA method (Castura, Antúnez, Giménez, & Ares, 2016). Unlike TDS, TCATA encourages the selection of more than one attribute over a time period. In Chapter 6 of our study, consumer panels were used in three different environments (lab, immersive, and real environment setting). Similarly, other studies have employed TCATA using consumer panels to evaluate various food products (bread, salami, cheese, etc.) (Ares et al., 2016), sparkling wines (McMahon, 2016), and probiotic chocolate flavoured milk (Oliveira et al., 2015). However, it is important to note that individual differences and panel consistency were not measured in this study. It is highly recommended that TDS panel consistency (Rodrigues et al., 2016) be measured in future studies to minimise and understand individual panel behaviour differences.

TCATA profiles for each music condition varied in the three environments (lab, immersive, and real environment setting). Complex flavour attributes such as cocoa, milky, and vanilla were cited more in the real eating environment compared to the laboratory condition. The changes in temporal sensory perception were consistent to our previous findings in Chapter 5.

Listening to liked and disliked music modulated sweetness and bitterness perception in the three environments (lab, immersive, and real environment setting). These changes in taste can be explained as taste perception requires simpler information processing compared to flavour. fMRI scans showed that during information processing of taste, less brain area was activated compared to flavour (taste and odour) information processing.

Flavour perception of cocoa, milky, and vanilla were not influenced by music varying in valence in the real environmental setting. However, changes in in these attributes were observed in the laboratory setting. This can be explained by the relationship of cognitive load and sensory suppression. Cognitive load is often described as the total amount of mental effort being used in information processing (Sweller, 1988). In order to decrease cognitive load, sensory suppression – the partial or complete blocking of sensory experience by a different stimulus, would need to occur (Sutter, Musseler, & Drewing, 2014). In our study, additional visual cues from real eating environments might have increased cognitive load (Regenbogen et al., 2012). This results in sensory suppression (Haggard & Whitford, 2004), which dampens the influence of music on flavour (higher level processing) in order to decrease cognitive load.

Applications of electrophysiology measures in sensory science – Chapter 7

The use of electrophysiology measures in sensory science is limited. To date, only three studies measured ANS responses of appearance, odour, and taste of food (de Wijk, Kooijman, Verhoeven, Holthuysen, & de Graaf, 2012), and predict sensory liking of breakfast drinks (de Wijk, He, Mensink, Verhoeven, & de Graaf, 2014) and juices (Danner, Haindl, Joechl, & Duerrschmid, 2014). Hence, the final objective of this research in Chapter 7 employed intrinsic electrophysiology measures (electrodermal, cardiovascular, and respiratory response) to confirm the influence of music on emotion ratings using a scale developed in Chapter 5. Skin Conductance (SC), Heart Rate (HR), Blood Volume Pulse (BVP), and Respiratory Rate (RESP) were selected as each of these measures reflect either sympathetic activity (e.g., electrodermal), parasympathetic activity (e.g., respiration rate), or both (e.g., cardiovascular response).

In Chapter 7, Partial Least Square Regression (PLSR) was used to examine these relationships. Further Partial Least Squares Path Modelling (PLS-PM) analysis of cardiovascular and electrodermal measures were then correlated with subjective rated emotions measured during consumption. Our results showed that the cardiovascular response was correlated positively with bitterness, milkiness, and cocoaness, but correlated negatively with sweetness, and creaminess. The electrodermal response was correlated positively with sweetness, and creaminess, but correlated negatively with bitterness, milkiness, and cocoaness. Electrodermal and Blood Volume Pulse were correlated positively with negative emotions (i.e. anger, contempt), which was positively correlated with increase in bitterness and creaminess. While cardiovascular response was correlated positively with positive emotions (i.e. amusement, happiness) which was positively correlated with increase of sweetness, milkiness, and creaminess.

In our study, sweetness induced a weaker response cardiovascular response and bitterness induced a stronger response. Rousmans, Robin, Dittmar, and Vernet-Maury (2000) also reported that pleasant sweet taste induced weaker ANS responses (electrodermal and cardiovascular), whereas bitter induced stronger ANS responses (electrodermal and cardiovascular). The ANS inactivation and activation was hypothesised due to the innate acceptance of sweet taste and innate rejection of bitter taste respectively (Steiner, 1977, 1979). Milkiness and cocoaness, which are reported to be drivers of liking in chocolates (de Melo, Bolini, & Efraim, 2009) were negatively correlated with SC and BVP measures, and positively associated with HR. Similarly, de Wijk et al. (2014) demonstrated that sensory liking of breakfast drinks was associated with increased HR and ST. In another study, Danner et al. (2014) further showed that disliked samples evoked higher galvanic skin responses than liked samples.

Interestingly, creaminess was correlated positively with SC and BVP measures, and negatively correlated with HR. This can be explained by the relationship between negative emotion and creaminess perception. ANS changes associated with creaminess has been correlated with evoked negative emotions of *fear* (Krumhansl, 1997), *displeasure* (Salimpoor, Benovoy, Longo, Cooperstock, & Zatorre, 2009), and *anger* (Marci, Glick, Loh, & Dougherty, 2007). In addition, Platte et al. (2013), demonstrated that after participants viewed a sad movie (negative emotion condition), higher intensities of fat taste were rated for 6% and 10% milk fat dairy solutions compared to watching neutral and happy movies.

A shortcoming of these studies was that they did not measure participants' baseline autonomic activity prior to the ANS measurement. Thus, their results were presented 'as is' without any data transformation (i.e. calculating the percentage change from baseline) and as such are difficult to interpret conclusively (Lin, Lin, Lin, & Huang, 2011; Miller & Ditto, 1989). Numerous studies in psychology (Crone, Somsen, Beek, & Van Der Molen, 2004; Lang, Greenwald, Bradley, & Hamm, 1993; Lin et al., 2011; Medvedev, Shepherd, & Hautus, 2015) have shown that a baseline measure is crucial as participants may have different autonomic responses when starting the experiment (Miller & Ditto, 1989). In our study though, we have taken into account individual variability that may be a confounding factor, as each individuals have discrete ANS signatures (Miller & Ditto, 1989). The ANS baseline of each participant was used to calculate percentage autonomic changes for each participant in order to achieve higher data quality in electrophysiological measurements by a process of normalisation.

PLSR was used to observe the correlation of electrophysiology measures to emotion, and sensory attributes similar to the de Wijk et al. (2014) study. PLSR results showed that electrodermal and blood volume pulse responses were correlated with self-reported negative emotions (i.e. anger, contempt), which was further associated with bitterness, and creaminess. In addition, cardiovascular response was associated with self-reported positive emotions (i.e. love, happiness), which was further associated with sweetness, and milkiness. However, PLSR lacked the ability to cluster manifest variables (each questions relating to a factor – i.e. *joy, happy, love*) to a latent variable (factors – i.e. Positive Emotion). Hence, PLS-PM was used in this study to confirm the relationship between intrinsic electrophysiology measures, subjective emotion ratings, and TDS ratings. In this study, intrinsic electrophysiological cardiovascular (HR and BVP), electrodermal (SC) and respiratory (RESP) measures were determined as the latent variables. Another latent variable was the emotions, which was further separated into positive and negative emotions. Positive emotions consisted of self-rated measures of *amusement*, *enjoyment*, *love*, *happiness*, and *satisfaction* as manifest variables. While negative emotions, consisted of self-rated measures of *anger*, *contempt*, *disappointment*, and *disgust* as manifest variables. Each TDS sensory attributes (sweet, bitter, milky, creamy, and cocoa) was also set as latent variables.

PLS-PM has previously been used extensively in marketing and consumer science in order to understand the influence of various factors in consumer behaviour, adopting the Mehrabian-Russel and Stimulus-Organism-Respose model (Russell & Mehrabian, 1977). Jang and Namkung (2009) adopted the Mehrabian-Russel Model and analysed their data using PLS-PM to investigate the effect of Product Quality, Atmospheric, and Service Quality of a restaurant to the Diners' Emotions (Positive or Negative), which influenced Behavioural Intentions of consumers. In this way, the direct relationship (significant or not significant, positive or negative correlations) between the latent variables (i.e. Product Quality → Emotion (Positive) or Emotion (Positive) → Behavioural Intentions) may be determined. Similarly, using PLS-PM in Chapter 7 enabled us to observe the direct relationship between the intrinsic ANS response to subjective ratings of emotions while eating and the influence of emotions to sensory perceptions (ANS (Cardiovascular, Electrodermal, Respiratory) → Emotions (Positive or Negative) → Sensory (Taste, and Flavour)).

Respiration Rate (RESP) and Blood Volume Pulse (BVP) measures were also included in this study as they validated measures of autonomic activity yet have not been measured in previous studies. Measurement of RESP and BVP would theoretically enable us to observe the third dimension of the VAD, namely dominance, which measures the controlling nature of emotion (i.e. *anger/fear*). Dominance is linked to attentional processing (Bradley & Lang, 1994) and the parasympathetic activity of ANS system (Lin et al., 2011). RESP and BVP measures have been linked with attentional processing. A study done by Iwanaga and Tsukamoto (1997) demonstrated that the sedative effect of music is linked to the activation of parasympathetic nervous system. In addition, Salimpoor et al. (2009) also showed that listening to neutral music significantly increased BVP followed by liked, and disliked music. Thus changes in BVP response in this study is associated with attentional processing.

Interestingly, in our study, RESP did not show any significant differences while listening to music, varying in liking, in isolation. This suggests that participants paid equal amounts of attention to the music. However, BVP measures in our study may not directly reflect attentional account as no significant differences was observed for RESP. Hence, we hypothesised that BVP measures in Chapter 7 only served as an internal measure standard, showing an inverse relationship with HR measurement with the function of music liking, and ensuring that HR measures was done correctly.

Chapter 9. Conclusion

Our results contributed to further understanding of the VAD model in explaining the effect of sounds and visual cues to perception of food pleasantness (Chapter 4). Participants exposed to pleasant stimuli (in this case, café environment) showed increased ratings of food pleasantness. In addition, combined audio-visual stimuli further increased food pleasantness and affective ratings. The influence of music to emotions and the influence towards temporal taste perception (Chapter 5) was also demonstarted. Temporal taste perception of gelati changed with music varying in valence. Listening to disliked music evoked negative emotions which was linked with the decrease in sweetness and increase in bitterness perception. On the other hand, listening to liked music evoked positive emotions which was linked with the increase in sweetnes and decrease in bitterness perception. It is thought that the ratings of chocolate gelati is not exclusive to the gelato's hedonic valence but also to the liking of the music. It is also important to note that participants in this study consumed gelati samples, which is an emotional food sample. Hence results found in this study may not extend to other food samples. This has been demonstrated by Fiegel et al., (2014) who reported that chocolate sample evoked more intense emotional responses, which influenced consumer's overall impression of chocolate. In contrast, bell-pepper sample did not evoke any emotional response and showed no changes in flavour intensity, pleasantness, texture impression, and overall impression.

The ecological validity of crossmodal effects of music in different environments (Chapter 6) was further examined. Cocoa, sweet, and milky attributes were the most cited attributes in the order of natural eating environment > immersive environment > laboratory environment. Interestingly, the crossmodal effect of music was evident only with taste attributes (sweetness and bitterness) in the real eating environment. No changes in flavour perception was observed in the real eating environment and has been associated with the attentional account of the music in the real environment compared to the laboratory setting. The application of ANS response in correlating taste and flavour with the function of emotions evoked by music (Chapter 7) was also established. A clear relationship between ANS response, emotions, and sensory perception was demonstrated. BVP and SC was positively correlated with subjective negative emotions (*anger, contempt, disappointment,* and *disgust*) and negatively correlated with positive emotions (*amusement, enjoyment, love, happiness,* and *satisfaction*) rating. HR was both correlated with positive emotions (positive association) and negative emotions (negative association). In addition, increase in electrodermal and cardiovascular (blood volume pulse) measures were associated with sweetness and creaminess. In contrast, decrease in electrodermal and cardiovascular measures were associated with bitterness, milkiness, and cocoaness. However, heart rate showed an inverse relationship with electrodermal and blood volume pulse measures.

The thesis provides a solid foundation and widespread research opportunities for future studies. Further research can be carried on from the VAD model perspective (Chapter 4), other audiovisual of eating environment (varying in arousal and dominance) and more diverse food stimuli should be used in order to confirm the influence of VAD towards food pleasantness. Chapter 5 explored the influence of emotions to sensory perception, participants' personality trait (i.e. Big Five Personality Test (Barrick & Mount, 1991)) should be measured and can be used to predict their behaviour and emotion response. Future studies may utilise odour, and artificial lights to create simulated environment inside the immersive dome (Chapter 6) to further understand the stimuli required to emulate real environmental testing. The success of ANS measures in our study (Chapter 7) to explain changes in sensory perception with auditory cues. Further research that can be explored include the use of other cardiovascular measures parameters such as High Frequency (HF%), Low Frequency (LF%), and other respiratory parameters such as Inspiratory Volume (Vi), and Expiratory Volume (Ve) that have been useful in predicting valence, and arousal responses. Functional magnetic resonance imaging (fMRI) scan may also be carried out to further understand the changes in our brain to further confirm results in this study.

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