The effect of background music on food pleasantness ratings

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Abstract
This study investigated whether samples of pleasant, neutral and unpleasant music can impact food perception. To this end, the pleasantness of three different types of chocolate gelati (milk chocolate, dark chocolate and bittersweet chocolate) was determined using 50 participants exposed to silence (the reference condition) and three music samples differing in self-rated preference. To measure hedonic responses to the gelati samples, the Time Intensity method was utilized to derive the maximum intensity of pleasantness and the area under the Time Intensity pleasantness curve. The presence of non-preferred music significantly decreased the pleasantness ratings of all three types of chocolate gelati tested, while preferred music increased perceived pleasantness ratings of dark and bittersweet chocolate gelati, but not milk chocolate gelato. Time Intensity parameters for pleasantness ratings did not differ significantly across the three different types of chocolate gelati in the silent condition, suggesting that listening to the music influenced gelati pleasantness ratings. This study demonstrated that the pleasantness of gelati changed with music valence. The findings echo previous studies emphasizing the importance of crossmodal effects between music and food perception.

Keywords
crossmodal integration, food pleasantness, gelato, music preference, time intensity

The multisensory nature of food perception remains an ongoing area of enquiry. Studies on crossmodal sensory integration suggest that one sensory modality can enhance the response of another if both are active concurrently (Sagiv & Ward, 2006). Though food and beverages are rarely consumed in a silent environment, the auditory modality has been relatively understudied in terms of crossmodal sensory interactions (Spence, Shankar, & Blumenthal, 2010). Indeed,
the acoustic environment in which we consume food can influence our food choices, rate of consumption, and hedonic experiences (Spence & Shankar, 2010). While a number of cross-modal interactions between taste and odour, and taste and colour, have been reported in the literature (Lawless & Heymann, 1999), comparatively less is known about the effect of the auditory modality on food perception. However, interactions between different pitches of musical notes and both food names and basic tastes (Crisinel & Spence, 2009), flavours of chocolate milk (Crisinel & Spence, 2011), and pleasantness ratings of chocolate (Crisinel & Spence, 2012), have been reported, indicating the existence of crossmodal interactions. More recently, relationships between music genre and perceptions of milk chocolate and bell peppers have been reported (Fiegel, Meullenet, Harrington, Humble, & Seo, 2014). Fiegel et al. reported that listening to jazz influenced the overall impression of milk chocolate significantly more than the other music genres used in their study. An earlier study of ethnic music indicated that “musical fit” can bias food product choices, but only in the absence of pre-existing preferences (Yeoh & North, 2009).

A consumer’s evaluation of a basic taste or flavour typically involves a hedonic judgement which can be reflexive in nature (e.g. disgust), or representative of more complex emotions involving the ability to endow unity, meaning, organization and value as gestalts are developed from basic sensory building blocks. During consumption, sounds can be directly associated with the food type (e.g. the crunch of a biscuit or the fizz of lemonade) and packaging sounds (e.g. the rustle of a candy wrapper), or indirectly associated (e.g. road traffic noise heard in a café). It is the latter source, sound indirectly related to the food source, that is the focus of the current study. Crisinel and Spence (2009) reported that high-pitched sounds were associated with both sweet and sour tastes, while low-pitched sounds were associated with a bitter taste. However, in their study food names presented on a monitor were used instead of real food samples. In a related study, Crisinel (2010) further investigated the effect of different instruments and tone pitches on 12 gustatory stimuli representative of the five basic tastes (bitter, sour, sweet, salt and umami) and seven complex flavours (almond, coffee, lemon, orange flower, peppermint, rose and vanilla). Low pitch notes generated by brass instruments increased bitterness ratings, while higher piano pitch increased ratings of sweetness. Using the same instruments and three types of chocolate, Crisinel et al. (2012) again concluded that pitch can influence taste.

When considering possible causal mechanisms for the impact of music upon food perception (and vice versa), it is often assumed that both (or multiple) streams of information are largely processed independently (i.e. bottom-up sensory analysis), and then later integrated into a multisensory gestalt (i.e. top-down perception). Furthermore, through the process of selective attention, an individual can shift focus to one-or-other modality (Kandel, Schwartz, Jessell, Siegelbaum, & Hudspeth, 2012). This suggests that sensory modalities can influence one another in two ways, directly or, more feasibly, indirectly. A direct influence (or direct coupling) is when the dynamics of one sensory modality entrains the dynamics of another, as might happen when odour intensity changes as a function of taste information (Veldhuizen, Nachtigal, Teulings, Gitelman, & Small, 2010). However, for biological reasons, this type of interaction may only occur for senses utilizing common brain structures, for example, between the auditory, visual and tactile modalities (utilizing the thalamus), or alternatively taste and smell (the insula cortex). Thus, when considering the interaction between flavour and music, more indirect mechanisms may be operating as consumers evaluate multiple-sensory dimensions in parallel.

Consideration of crossmodal mechanisms is, at the current time, still a matter of speculation, though several potential candidates present themselves (Spence & Shankar, 2010). First, emotional states induced by acoustical stimuli may partly explain the crossmodality between the chemosenses and the auditory sense (Schubert, 2004). The “arousal-mood” hypothesis argues that music that is arousing and elicits a positive mood places the consumer into a more engaged
and positive mind frame, and is therefore more likely to engage and positively respond to other stimuli (Schwarz & Clore, 2003). Stroebele and de Castro (2006) demonstrated that food intake increased in an environment eliciting intense emotional arousal compared to a low arousing environment. Second, distractive stimuli that direct attention away from goal-relevant information may interfere with stimulus processing associated with other modalities. Stafford, Fernandes, and Agobiani (2012) investigated the effect of distracting sounds on sweetness ratings using music, a repeating news story played in the background, and a combination of the two. The music condition resulted in higher sweetness ratings of alcoholic beverages compared to the other two conditions, suggesting that distracting stimuli can impact sensory or perceptual processes. Finally, a third approach involves classical conditioning, whereby consumers learn associations between otherwise unrelated stimuli, such as music commonly played in restaurants or bars and feelings of satiation. Jacob (2006) reported that participants who listened to drinking songs had increased consumption of alcoholic beverages.

If music can influence hedonic responses to food and, by implication, flavour, then subjective evaluations of music are critical if one is to understand how music and flavour interact. Gestalt theory, the “arousal-mood” hypothesis and Russell and Mehrabian’s Environmental Model (Russell, 1980) all emphasize the importance of subjective factors such as music familiarity and preference when considering emotional response. Therefore the approach we take is consistent with the referentialist approach to music and emotion, in contrast to the absolutist approach arguing for a direct coupling between music structure and emotion. Furthermore, Spence and Shankar (2010) draw attention to the phenomenon of sensory dominance, noting that audition is the dominant sense when individuals judge objects or events that change over time. This dominance is, however, unlikely to be invariant and there will be some shift between modalities as the stimuli contained in an individual’s hosting environment are in a constant flux. Thus, when examining crossmodal influences between any pair of senses, including the chemosenses and the auditory sense, it is important to consider the temporal relationships between the stimuli and subsequent sensations and perceptions they elicit.

The aim of the current study is to investigate how the pleasantness ratings of three different flavours of chocolate gelati change across time, with the gelati being consumed during a silent period or in the presence of music. Music was chosen because, from scrutiny of past studies, it is evident that there is a bias towards simple acoustic contexts such as simple tones or chords from a single instrument. In the interests of external validity, it is important to examine the effect of more complex auditory structures that are more applicable in real food consumption environments. Chocolate gelati was chosen because emotional eating is often associated with sweet foods, and the influence of music on gustatory pleasantness has been shown to be amplified by using emotional foods such as chocolate (Fiegel et al., 2014). Here, pleasantness is defined as a positive psychological state characterized by enjoyment. Thus on the basis of theory and related empirical evidence found in the literature, we hypothesized that listening to preferred music, as determined by the participants a priori, will enhance the pleasantness ratings of all three chocolate gelati, while listening to non-preferred music will reduce pleasantness.

**Method**

**Participants**

Participants (N = 50) were either university students or staff (29 females, 21 males), aged between 19 and 55 years (M_age = 29 years, SD = 2.1). The ethnic profile of the study was 52% Asian, 41% Caucasian and 7% others. Participants were instructed to refrain from any food,
tea, coffee or smoking at least 30 minutes prior to the trial. All participants provided informed consent and received vouchers for their participation. Participants in this study were informed that the research investigated different formulations of ice cream. Participants were not told any other information in relation to crossmodality studies until they were debriefed afterwards, and were asked to strictly follow the onscreen instructions during the experiment.

**Materials**

*Music stimuli.* Fourteen musical genres (blues, folk, classical, jazz, alternative, heavy metal, rock, country, religious, pop, funk, hip-hop, soul and electronica), as described by Rentfrow and Gosling (2003), were used to guide song selection and subsequent measures of music preference. Songs were selected with assistance from Apple iTunes’ music classification system. As part of the process an informal focus group consisting of eight people (21 to 35 years old), who were regular music listeners (at least two hours per day), agreed on one song that best represented each genre (Table 1). The audio samples (bit rate = 256 kbps) were then modified using Adobe Audition CS6 (Adobe Systems Inc., U.S.). 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 all songs scaled to 70 dB SPL using a Brüel and Kjær measuring amplifier. This can be considered a reasonable volume to present songs while avoiding amplitudes that could cause discomfort or hearing loss. The audio samples were then presented by a standard PC sound card to a Sennheiser headset (Series HD 518: Sennheiser Electronics GmbH and Co. KG). Prior to data collection, a pilot study was undertaken to determine the optimum music listening time during gelati consumption using the Time Intensity (TI) method (Lawless & Heymann, 1999). Here participants were exposed to the 14 different musical genres and a silent condition while consuming and evaluating gelati samples using a hedonic unstructured line scale. Results indicated that a 45-second interval

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**Table 1.** Musical genres, recording artists, songs and frequency of musical preference used in the current study.

<table>
<thead>
<tr>
<th>Genre</th>
<th>Artist</th>
<th>Song</th>
<th>Preferred</th>
<th>Neutral</th>
<th>Non-Preferred</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classical</td>
<td>Ludwig van Beethoven</td>
<td>Für Elise</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Folk</td>
<td>Mumford and Sons</td>
<td>Sigh No More</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Alternative</td>
<td>Alanis Morissette</td>
<td>Narcissus</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Rock</td>
<td>Gotye Featuring</td>
<td>Somebody That I Used To Know</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Country</td>
<td>Lee Brice</td>
<td>A Woman Like You</td>
<td>2</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Pop</td>
<td>The Wanted</td>
<td>Glad You Came</td>
<td>2</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Soul</td>
<td>Kanye West</td>
<td>All of the Lights</td>
<td>7</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Blues</td>
<td>Ray Charles</td>
<td>I Got A Woman</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Jazz</td>
<td>Louis Armstrong</td>
<td>La Vie En Rose</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Heavy Metal</td>
<td>AC/DC</td>
<td>Thunder Struck</td>
<td>3</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Religious</td>
<td>Larnelle Harris</td>
<td>Dream On</td>
<td>8</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Funk</td>
<td>James Brown</td>
<td>Living in America</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Hip Hop</td>
<td>Black Eyed Peas</td>
<td>Can’t Get Enough</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Electronica</td>
<td>Jack Back</td>
<td>Wild One Two</td>
<td>4</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>
of music was sufficient to rate the pleasantness of the gelato, and for this study only the first 45 seconds of a song was presented.

**Gelato preparation and presentation.** Three different flavours of gelato were selected: dark (DC), bittersweet (BC) and milk (MC) chocolate, being bitter, both sweet and bitter (transitional) and sweet, 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%) had the highest concentration, followed by BC (15%) and MC (10%). The highest milk content was MC (15%), followed by BC (8%). The DC gelato did not contain any milk. The MC flavour had the smallest cocoa-to-milk ratio compared to BC, and was less bitter than BC. This design of having bitter, transitional and sweet samples follows Crisinel and Spence (2012).

The DC, BC and MC gelato samples were prepared by a local gelato manufacturer, and samples then transported a short distance to the sensory laboratory using polystyrene boxes, where they remained refrigerated (~4º C) until served. Then 2.0 ± 0.1 gram of each gelato flavour was placed separately into a 25 ml plastic container coded with a three-digit random number. The order of samples was randomized to avoid order and carry-over effects (Macfie, Bratchell, Greenhoff, & Vallis, 1989). The randomized sets of samples were placed in an insulated container containing crushed ice, and refrigerated until evaluated. The samples were served under white light.

**Procedures**

To begin, all 50 participants listened to the first minute of each genre’s representative song and then made a rating using an unstructured 100 mm line scale anchored with “extremely non-preferred” on the left end and “extremely preferred” on the right end (where 0 mm corresponds to the score of 0, and 100 mm corresponds to 10.0). After judging all 14 genres, each individual’s ratings were ranked from the highest to the lowest. The first ranked and the last ranked music samples were the preferred and non-preferred music, respectively, for that individual. Mid-range preferred music, which we labelled “neutral” after Bradley and Lang (2000), was determined as the seventh ranked music genre. A one-way ANOVA and subsequent post hoc testing showed that the mean preference ratings for those songs classified as preferred (**M** = 82 mm, **SD** = 5.2), neutral (**M** = 47 mm, **SD** = 3.7) and non-preferred (**M** = 21 mm, **SD** = 4.6) music were significantly different for any pairwise comparison (**p** < .05).

Time Intensity (TI) measurements of pleasantness were obtained for the three different types of gelati under four sound conditions: preferred, neutral and non-preferred music conditions, and a silent condition. As with previous research (e.g. Yeoh & North, 2009) a silent condition was included to act as a reference condition, without music to induce emotion or directing attention. Each sensory booth, of which there were eight in total, contained a computer screen presenting instructions on how and when to consume the gelati samples over time. Pleasantness ratings of all gelati samples were obtained using an unstructured time intensity scale of 100 mm (where 0 mm corresponds to the score of 0, and 100 mm corresponds to 10.0), with “Pleasantness” being displayed on the top, middle of the computer screen. The scale was labelled “Extremely unpleasant” on the left end and “Extremely pleasant” on the right. The participant was asked to immediately report any change in the pleasantness of the gelato sample while listening to a 45-second piece of music or silence; in other words, from the first bite to the swallowing and after taste sensations, if present. Note that, as music had been rated a priori, participants were asked to rate the pleasantness of the gelati only.
As soon as the participant clicked on the 100 mm unstructured line scale on the computer screen, the music (or not for the silent condition) began playing, and the participant was prompted to place the gelato sample into their mouth. After 25 seconds the participant was instructed to swallow by an onscreen instruction above the pleasantness scale. The action of clicking the line scale on the computer screen activated the program to record the pleasantness ratings for up to 45 seconds, with all ratings recorded using FIZZ sensory data acquisition software (FIZZ Network v2.46b, Biosystemes). When the participant perceived a change in pleasantness, they adjusted the onscreen scale corresponding to the new level of pleasantness (or unpleasantness). Detailed instructions were given to minimize variation in consumption behaviour. A compulsory 45-second break in between samples was provided, during which the mouth was cleansed with filtered water. After this break, the participant was directed to the next flavour or music/silent condition. On completion of all 12 trials (3 flavours by 4 sounds conditions), the computer screen greyed out to indicate the end of the experimental session. The chronological order of the session's components can be viewed in Figure 1. The presentation order of the four sound conditions and the three gelati flavours was randomized across participants. After the session, the participants were asked to rate the degree of familiarity towards the three different flavours of chocolate gelati, as previous studies had shown the importance of food familiarity with food acceptance and hedonic likings (Stein, Nagai, Nakagawa, & Beauchamp, 2003).

**Data analysis**

Data were analysed according to Chung, Heymann, and Grün (2003). The TI parameters were derived by first decomposing the TI curve into an ascending phase (which may be preceded by a latency phase), a stationary phase (plateau) and a descending phase (which may be followed by an end phase). The estimated TI parameters, compared across the music/silent and gelato samples, were maximum intensity (IMax), plateau duration (DurPl) and area under the curve (AreaTse). Other TI parameters have been useful in exploring time-related parameters, for example, the duration of pleasantness, which is important when considering semi-solid foods such as gels and ice creams (Prindiville, Marshall, & Heymann, 1999, 2000). The durations (measured in seconds) of increase (DurInc) and decrease (DurDec) values coincide with the time needed to achieve maximum pleasantness intensity and to decrease to

![Figure 1. Summary of a TI session. Time is in seconds.](image-url)
baseline respectively. Figure 2 presents a hypothetical TI curve showing the parameter extraction by the FIZZ Calculator software (FIZZ Calculator v2.46b, Biosystemes). Pleasantness data were analysed using two-way ANOVA to observe the main effects of music and gelato flavour and the interactions between these two factors. Music and gelato were classed as fixed effects and participants as random effects. Alpha was set to .05 (two-tailed) for all the analyses.

**Ethics statement**

Ethics was approved by the Auckland University of Technology Ethics Committee (AUTEC: 12/79). Informed consent was obtained from the participants prior to the commencement of the experiment.

**Results**

**Effect of music on perceived pleasantness of chocolate gelati**

Across the four music conditions, MC had the highest average pleasantness ratings of the three gelati. It was also the most familiar chocolate gelato flavour for most of the participants (80%), and the sample with the highest milk content. Values of IMax, representing the maximum pleasantness rating perceived by a participant while consuming a gelato sample, is plotted as a function of sound condition in Figure 3 (left plot). It is evident that the reference condition (i.e. silence) had little impact on the perceived pleasantness of each gelato type compared to the other music conditions. When non-preferred music was played, a sharp drop in mean IMax was noted for bittersweet and dark flavours, but only a shallow drop for the milk chocolate flavour. Neutral music was associated with increases in mean IMax across the three
flavours, particularly the bittersweet flavour. For preferred music, there was a decrease in IMax for both the milk and bittersweet gelati. This pattern of results was duplicated when AreaTse was plotted (Figure 3, right plot), and this covariation is concordant with other TI studies where only IMax and AreaTse were reported (Lawless & Heymann, 1999). For the IMax data it was apparent that the mean AreaTse estimates did not differ significantly across the three gelato flavours for the silent condition, confirming that the changes in pleasantness ratings were likely attributable to the music.

Music was found to have a significant main effect on DurInc, DurDec and DurPl (see Table 2). DurInc was significantly less for preferred music, while non-preferred music significantly increased DurInc relative to preferred music. DurDec was significantly greater for preferred music, while non-preferred music was significantly lower. For the perceived duration of maximum pleasantness (DurPl) metric, gelati Samples played with music had significantly longer DurPl compared to the silent condition, which indicates that the changes in pleasantness were due to a main effect of music. Note too that IMax and AreaTse parameters did not differ significantly in the silent condition across the three chocolate-flavoured gelato samples, suggesting that the changes in pleasantness ratings were likely attributable to the music conditions.

Music and chocolate gelato flavour interactions

From the data it is evident that music preference influenced the pleasantness ratings of all three chocolate gelato types. Both the main effects of flavour and music, and all of the interaction terms with the exception of the DurPl interaction, were statistically significant (Table 2). The high F-values for the interactions strongly support the notion that pleasantness was modulated by both flavour and music. Interaction plots for IMax and AreaTse are displayed in Figure 3, and revealed similar trends. When participants listened to preferred music, pleasantness TI values
for IMax, AreaTse and DurInc (Table 2) were high for BC and DC but low for MC, while for non-preferred music, the values were low for BC and DC but high for MC. As for neutral music pleasantness, TI values for IMax, AreaTse and DurInc (Table 2) were high for BC and MC but low for DC flavour.

### Discussion

Our study investigated the impact of music on hedonic responses to gelati ice cream. Whereas other studies (e.g. Fiegel et al., 2014) focused on the association between music genre and food perception, we examined the relationship between music preference and food perception. Specifically, the music to which participants were exposed was selected using a priori ratings of music preference, endowing a degree of adaptability upon the research design. The main finding was that hedonic judgements of gelato consumed in the presence of music were impacted by the valence of the music, that is, preferred, neutral or non-preferred songs. Silence, which was employed as a reference condition, had a non-significant effect on gelati ice cream pleasantness ratings, suggesting that it was the music that was altering hedonic judgements. The similarity in preference ratings in the silent condition, taken with the rest of data, supports the conclusions of Yeoh and North (2009) that music exerts a maximal influence when there are no clear preferences for one food product over another. However, analysis of interaction terms suggested that the effect of subjectively-rated music depended on the type of gelato, indicating that the sensory attributes of the food also contribute to the effect that music has on hedonic ratings.

In general, our findings are consistent with those previously reported in the literature. In relation to the main effect of gelato flavour on pleasantness, Prindiville et al. (2000) reported that higher milk fat concentrations produced more creaminess and smoothness, as well as a
less intense cocoa flavour. Thus the creaminess and smoothness of our MC flavour likely contributed to its higher overall average pleasantness ratings. In terms of the main effect of music on food pleasantness, Woods et al. (2011) demonstrated the impact of background noise on food taste (sweetness and saltiness), texture (crunchiness) and liking. Fiegel et al. (2014) likewise reported that music can alter flavour pleasantness. Both Fiegel et al. (2014) and Woods et al. (2011) speculate as to the underlying mechanisms that may account for the effects of auditory stimuli upon overall impressions of gustatory stimuli. In keeping with Spence and Shankar (2010), we relate our data to three such mechanisms, moderation of attention, arousal or affect, and apply them to each of the preferred, neutral and non-preferred music conditions.

**Pleasantness ratings obtained in the presence of preferred background music**

When the participants tasted gelato in the presence of preferred music, mean pleasantness TI values for IMax, DurInc and AreaTse were significantly lower for the MC sample compared to the BC and DC gelato (see Table 2). This finding was unexpected, given that DC and BC contained less milk and were more bitter than the MC sample. Additionally, the IMax and AreaTse values for MC were not significantly different in the preferred music and silent conditions (see Figure 3). When considering attentional mechanisms, these findings invite an intriguing conjecture, consistent with the notion of sensory dominance. In attracting attention, preferred music may reduce the pleasantness of a liked food (albeit judged here as relatively more “liked” indirectly by the familiarity ratings), possibly by drawing attention away from its favourable sensory qualities. Furthermore, for BC and DC, preferred music may reduce the unpleasantness of less liked food by redirecting attention away from it, and thus a less critical review of the gelato may occur.

Konečni (2008) argues that music induces basic emotions, and environmental sounds and music were suggested by Spence and Shankar (2010) to evoke emotional responses such as pleasure and dominance. Increased pleasantness ratings of BC and DC gelato with preferred music might have been induced by a positive state in individuals that, in turn, impacted their evaluation of the gelato. Additionally, for BC and DC, the overall increase in perceived pleasantness while listening to preferred music could be explained by mechanisms working in tandem—pertinently, induction of positive moods and increased arousal. Studies have reported that listening to preferred (or liked) music can induce a positive mood in shopping patrons (Alpert, Alpert, & Maltz, 2005), and a review by Schwarz and Clore (2003) suggested that when participants experience positive mood states, they are more likely to make positive assessments of stimuli. Further, positive mood states have been associated with heightened arousal, which may increase sensitivity and lower taste thresholds, thereby amplifying taste perceptions (Platte, Herbert, Pauli, & Breslin, 2013). Serotonin and noradrenaline are brain neurotransmitters implicated in positive mood states (Young, 2007), as well as arousal and cognitive alertness (Paus, 2000). Heath, Melichar, Nutt, and Donaldson (2006) found that administration of serotonin reduced sucrose thresholds by 27%, while noradrenalin reduced them by 15%. Thus for the current study, the changes in taste perception for BC and DC may be explained by changes in mood state and arousal, such that when listening to preferred music an increase in pleasantness perception occurs. Major challenges to this explanation are, however, that it does not hold for the MC gelato and the time lag associated with the production of neurotransmitters.

**Pleasantness ratings obtained in the presence of neutral background music**

Our study is the first to measure food pleasantness when listening to a neutral music genre. For neutral music, mean IMax, DurInc and AreaTse values were significantly higher for BC and MC
compared to DC (see Table 2). Of remark, however, is the trend that all three gelati types increased their average TI parameters relative to the non-preferred music condition. In situations where music competes for attention with another task, for example, reading, it has been reported that the music may be filtered out by selective attentional processes to facilitate concentration on goal-directed tasks (Madsen, 1987). In this study, at least speculatively, the neutral music may have been phased out of awareness and thus did not direct participants’ attention, thereby leaving more cognitive capacity for food assessment. Alternatively, it could be argued that neutral music induces neutral moods, which may also be related to food perception. Platte et al. (2013) reported that mildly depressed patients were unable to discriminate high or low fat samples after positive or negative mood inductions. However, their participants were able to discriminate these samples after inducing a neutral mood. Bradley and Lang (2000), investigating the physiological effect of sounds as a function of valence ratings (namely, pleasant, unpleasant and neutral), noted that pleasant and unpleasant sounds were both rated as more arousing than neutral sounds. Thus reduced arousal is also a potential mechanism to explain the increment in TI parameters from non-preferred to neutral music, and for MC and BC, the reduction from neutral to preferred music.

Pleasantness ratings obtained in the presence of non-preferred background music

For non-preferred music, average IMax, DurInc and AreaTse values (see Table 2) for BC and DC gelati were significantly lower than for MC gelato. Ambient sounds may induce positive or negative emotions, leading the participant to enjoy their food either more or less (Helsing, 2012; Johansson, Holmqvist, Mossberg, & Lindgren, 2012; Konečni, 2008). Johansson et al. (2012) suggest that non-preferred music engages individuals in a negative way. Thus, for IMax, the overall decrease in pleasantness with non-preferred music relative to the silent condition may be explained by the induction of a negative mood state, as such states are associated with negative judgements of stimuli (Schwarz & Clore, 2003). Additionally, the hedonic tone of auditory stimuli directly influences arousal levels (Gomez & Danuser, 2004), and for sounds rated as highly-arousing, Bradley and Lang (2000) showed that unpleasant sounds were associated with greater physiological arousal than neutral or pleasant sounds. Salamon, Bernstein, Kim, Kim, and Stefano (2003) reported that listening to non-preferred music increases self-reported anxiety and blood pressure, an accepted marker of autonomic arousal. It may be then, that increased arousal caused by listening to the non-preferred music may have reduced the pleasantness ratings for the three gelati. Alternately, the ability to concentrate is degraded in the presence of non-preferred music (Johansson et al., 2012), and this may have influenced pleasantness ratings by acting as a distracter (Spence & Shankar, 2010). By its very nature, multi-tasking (e.g. rating a stimulus while having attention directed to an extraneous event) manifests an increase in cognitive load. Similarly, listening to non-preferred music might have increased the cognitive load of our participants and so, relative to the silent condition, pleasantness ratings dropped as attention became divided.

Pleasantness across music preference conditions

Arguably, an ordinal relationship exists across the three music conditions (non-preferred, neutral, preferred), and these pleasantness functions, depicted in Figure 3 for the three gelati types, are worth describing. Only pleasantness ratings for the DC gelato exhibited a monotonic function across music preference. For MC gelato, an inverse quadratic function appears to best represent the IMax and AreaTse functions, and to a lesser degree this is true of the BC function.
This variability across the three gelati represents a substantial theoretical challenge, reflecting the complexity of hedonic responses, and the multitude of variables that will need to be accounted for in any model predicting TI parameters. For our data, the quantitative and qualitative differences in the pleasantness functions may possibly be explained by properties intrinsic to the gelati themselves (e.g. cocoa or fat content). In relation to the three possible explanations for the trends in the data, none of the arousal, distraction or mood state hypotheses sufficiently account for the data at large. Further complications arise in that the results can be accounted for by considering more than one explanation and, furthermore, that bi-directional relationships likely exist between the front-runner hypotheses as described by Spence and Shankar (2010). Figure 4 is a schematic representation illustrating the challenge in disentangling the influences of the three dominant theories in the contemporary literature. In this scheme, distraction can lead to annoyance, which in turn increases arousal and decreases mood state. Arousal, in turn, is associated with hypersensitivity to stimuli, and may make individuals more vulnerable to distraction. Extreme mood states have been correlated with hyper- or hypo-arousal in the clinical literature, and depression (associated with hypo-arousal) is linked to noise sensitivity, a trait associated with individuals who are more likely to attend to irrelevant ambient sounds and be annoyed by them (Stansfeld, 1992). Furthermore, attention may be directed reflexively (i.e. involuntary) or in a controlled manner (i.e. voluntary), with directed attention more likely to be associated with irritation or annoyance, that is, negative emotions.

**Limitations of the current study and directions for future research**

A limitation of the current study is the laborious procedure participants experienced and the potential for fatigue or satiation effects to influence gelato pleasantness ratings. To what degree counterbalancing negated these effects we cannot estimate, though counterbalancing is considered best practice for dealing with order effects. The results suggest that playing neutral and preferred music increases gelati pleasantness compared to non-preferred music. However, while we can conjecture that the valence of the music was a factor in the variability of gelati pleasantness ratings, we cannot broaden our generalization to specific music genres. What is more, as no analysis of the songs themselves was undertaken, we cannot comment on whether specific aspects of the music (e.g. tempo, mode or percussiveness) were moderating the relationship between music exposure and enjoyment (or not) of the gelati. This would be an opportunity for future research to test the veracity of the so called “absolutist approach”, with previous psychophysiological findings indicating that a song’s tempo, mode and percussiveness can modulate and direct emotions, including arousal and mood (van der Zwaag, Westerink, & van den Broek, 2010).
Further research could enhance external validity by increasing the complexity of the gustatory stimulus, for example, a meal typical of an everyday dining situation. Ecological validity could be improved by relocating the experiment to a more real-world situation, such as a café or home dining table.

**Conclusion**

Non-preferred music genres decreased the pleasantness ratings of all chocolate gelati relative to a silent condition. Neutral music increased perceived pleasantness ratings more than preferred music for the milk chocolate gelato, which participants were more familiar with. Additionally, preferred music increased perceived pleasantness ratings of less familiar dark and bittersweet gelati. These findings are discussed in terms of the arousal-mood hypothesis. The exact mechanism(s) that underlie the interaction between music and food perception have yet to be elucidated, with no dominant approach able to explain the current findings. Future research is required to disentangle the influences of arousal, attention and mood upon perceived pleasantness of one stimuli (e.g. gelato) when presented simultaneously with another (e.g. music). These findings invite several intriguing implications, including increasing the consumption of non-preferred foods by concurrently presenting preferred music, or decreasing the consumption of preferred (but unhealthy) foods by concurrently presenting non-preferred music. Crisinel and Spence (2009) suggest that music could be played to patients with impaired gustation to increase the enjoyment of eating. For advertisers and retailers, however, individual differences in music preference remain an ongoing challenge, and our results here suggest that the selection of neutral background music may still confer an advantage.

**Acknowledgements**

The authors would like to thank Ms Brid Lorigan for her generous help and support throughout the study.

**Funding**

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: School of Applied Sciences at Auckland University of Technology.

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