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Lunch melodies: Investigating the impact of music on emotions, hunger, liking, and psychophysiology while viewing a lunch meal

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ABSTRACT

Sensory cues like music can influence our behaviour towards food. In the present study, the effect of music on hunger, fullness, desire to eat and liking of foods, while viewing real lunch food items, was investigated. To this end, emotions and physiological measures were obtained to understand the changes in hunger, fullness, desire to eat and liking. The study aimed to examine changes in hunger, fullness, desire to eat, and liking when viewing a lunch meal under silent and varying music conditions. Additionally, the study explored the potential role of emotions to explain these changes. A crossover experimental design was employed using 50 participants (17 males and 33 females) who observed lunch food items during a silent condition (control), or while listening to either liked or disliked music. The findings demonstrate the cross-modal influence of music on hunger and food liking ratings when viewing food. Hunger ratings were higher and more negative emotions were evoked while viewing lunch food items and listening to disliked music. In contrast, in the silent and liked music conditions, which elicited more positive emotions, there were increased ratings of healthy and unhealthy food pleasantness, overall food liking, and food satisfaction. Electrophysiological measures of heart rate (HR) and skin conductance (SC) were obtained while listening to music and viewing a lunch meal. Viewing food items while listening to disliked music evoked negative emotions and significantly increased SC compared to liked music or silent conditions. Viewing the food items under the silent condition evoked positive emotions and significantly increased HR compared to listening to liked and disliked music. This study showed that the participants' emotions, hunger level, liking, and electrophysiological responses when viewing food are influenced by music that varied with liking. Results from this study may assist in enhancing dining experiences, as well as influencing food choices and satisfaction with meals.

1. Introduction

Music can influence consumer behaviour in retail and restaurant environments. Previous studies on music in retail stores have focused on how background music influences time spent in shops and eateries. Caldwell and Hibbert (2002) reported that slow-paced music significantly increased consumer spending and time at a restaurant compared to fast tempo music. Drinking songs (e.g., The Drunken Sailor song) significantly increased time and money spent in a bar compared to Top 40 songs and cartoon songs (Jacob, 2006). Further research showed that playing traditional music increased food and drink spending in a Japanese restaurant more than pop or a mixture of pop and traditional music (Choo et al., 2020). However, in a Mexican restaurant, the sale of food and beverages was higher when mixed music was played than either pop or traditional music in isolation. To date, only a few of studies have investigated how music influences visual attention to food and the desire to eat (Jing et al., 2024).

Different styles of music can influence food selection. Muniz et al. (2017) investigated the effects of listening to Italian and Thai folk songs on the selection of Italian and Thai food menu items. Italian food items were selected more when participants listened to Italian folk songs than when listening to Thai folk songs or an Italian background restaurant sound. In addition, Thai food items were selected more while participants listened to Thai folk songs compared to Italian folk songs. Zellner et al. (2014) showed that chicken parmesan was selected more when Italian music was played, while seafood paella was selected more when Spanish music was played. In another study, Chinese participants increasingly selected Eastern food image items over Western items while

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listening to Eastern music compared to Western music, while the opposite was found with Danish participants (Peng-Li et al., 2020).

The effect of different sound environments on hunger, fullness, and the desire to eat has also been studied. Lowe et al. (2018) exploring the effect of sound frequencies in sandwich advertising on the perceived desirability of consuming a sandwich, found that participants with higher hunger levels expressed a greater desire to eat a sandwich when exposed to a lower acoustic pitch compared to a higher acoustic pitch. Conversely, participants with lower hunger levels had significantly greater desire to eat a sandwich when exposed to a lower acoustic pitch sound. However, Kaiser et al. (2016) found no significant changes in hunger and appetite ratings due to the impact of music (German and English pop songs) and sound transmission mode (loudspeakers or headphones). Similarly, Whitelock et al. (2018) examined the impact of different conditions (silent, listening to a recording of a bird migration story, and focusing on food characteristics from pre- to post-meal) on participants' consumption of pasta. They reported no significant changes in hunger ratings across the different conditions.

Distraction has been identified as a potential mechanism explaining changes in hunger, fullness, and desire to eat. Ding et al.(2019) reported that participants who performed tasks while eating had significantly higher post-hunger levels than participants who ate without any distraction. Brunstrom & Shakeshaft (2009) reported that healthy female participants who consumed sponge cake while playing a computer game were less satiated compared to a silent condition, indicating that arousal may be a factor. Blass et al. (2006) further reported that hunger ratings from pre- to post-meal were significantly higher in both normal and over-weight participants who consumed macaroni, pizza and cheese while watching TV than when listening to music. Oldham-Cooper et al. (2011) reported that participants who played computer games during lunch had significantly reduced post-meal fullness compared to a distraction-free condition. However, post-meal hunger levels were not significantly different between both distraction and no-distraction conditions, though males reported significantly greater hunger than females' post-meal. Long et al. (2011) investigated pasta intake by healthy young women instructed to focus on the sensory characteristics of food (focused attention), to listen to 30 min of a story (distraction), or to consume in silence. In their study fullness ratings were higher when consuming pasta in silence than the focused attention or distraction conditions.

Emotions can be influenced by hunger. MacCormack and Lindquist (2019) reported that participants who fasted for more than five hours provided significantly higher ratings of negative and high arousal emotions (e.g., anger, contempt, disgust, embarrassment, fear, guilt, hate, shame, and stress), than satiated participants who had eaten a meal within the past hour. In another study, hungry women (fasting for 14 h) experienced more negative emotions (e.g., higher tension, anger, fatigue, and confusion) and less positive emotions than satiated women (Ackermans et al., 2022). Swami et al. (2022) further reported that greater levels of hunger is associated with greater feelings of anger and irritability compared to participants who had snacks between main meals. However, none of these studies specifically examined the effects of the eating environment on the intensity of hunger-related emotions.

The sense of vision plays a crucial role in the initial evaluation of food when making a choice. (Delwiche, 2012; Spence et al., 2016). Viewing foods can influence emotion and music selection. Kontukoski et al. (2016) found that viewing an image of steak increased the selection of music (e.g., classical and jazz) that induced peacefulness, transcendence, tenderness, and joyful emotional states. On the other hand, the viewing of salad resulted in increased selection of music (e.g., pop and soul) that evoked peacefulness and joyful emotional states. Emotions evoked by music and sound can further influence food purchase and liking. Biswas et al. (2018) explored the effect of high and low levels of background music on measures of perceived relaxation or excitement using a pulse oximeter. The results showed that listening to background music at 70 dB SPL resulted in a higher heart rate than 55 dB SPL. Moreover, this study also investigated the effect of background music on the sale of healthy and unhealthy foods. The results reported that background music playing at 55 dB SPL increased sales of healthy food items by inducing relaxation, while the music increased the sale of unhealthy food items by inducing excitement at 70 dB SPL. A recent study by Peng-Li et al. (2022) found that listening to audio samples of the ocean increased the likability of healthy food images compared to unhealthy food images, possibly by inducing relaxation. However, listening to restaurant sounds significantly increased arousal but resulted in no significant differences between the liking of healthy and unhealthy food images.

Emotion can be measured either subjectively, using self-report measures, or objectively using physiological measures, and both have been used to study the emotions elicited by images of food. Nederkoorn et al. (2000) explored how food varying in liking influenced physiological responses like heart rate (HR), blood pressure (BP), skin conductance (SC), and salivation in women. They found that HR, BP, and SC significantly increased during food exposure compared to baseline measurements taken before and after food exposure. Kuoppa (2016), investigating the effect of viewing positive (e.g., cake, sweets) and negative (e.g., mouldy bread or half-incubated balut egg) food images on heart rate (HR), reported that HR significantly decreased while viewing positive but not negative food images. Verastegui-Tena et al. (2017) found positive (chocolate) and negative (worms) images significantly decreased HR compared to looking at a neutral image (soy), and SC significantly decreased when viewing negative images compared to positive and neutral images. Viewing images of Japanese food have been found to influence measures of HR, SC, and facial electromyography (EMG) signals (Sato et al., 2020), with EMG activity positively correlated with ratings of food liking, desire, and valence, and SC positively correlated with desire. These findings suggest the possibility that autonomic nervous system activity is linked to the hedonic response to food images (Stuldreher et al., 2023). However, a search of the literature revealed few studies which involved individuals viewing real food under different auditory conditions.

The effects of music on physiological responses during food consumption are influenced by varying emotional states. Etzel et al. (2006) examined the effects of 12 music samples, selected to induce happiness, sadness, and fear, on physiological measures (HR and respiration rate, RESP). They found that mean breathing rate was significantly decreased when listening to music that evoked sadness compared to music that evoked happiness and fear. Additionally, Salimpoor et al. (2011) reported significant increases in RESP and HR when listening to pleasurable relaxing music compared to neutral music. A study by Xu et al. (2019) showed that HR and SC significantly increased when listening to unpleasant café machine sounds compared to more pleasant café-forest and café-bird soundscapes after eating ice cream. When listening to the café machine soundscape, ice-cream was further associated with bitterness perception and negative emotions (e.g., anger, disgust, disappointment, and contempt). Xu et al. (2019) demonstrated that SC was significantly higher in a university study area environment compared to a laboratory environment when eating chocolate ice cream, and that HR was significantly lower when consuming ice cream in the university study area compared to a busy bus stop environment. Furthermore, electrophysiological responses can be regulated by music when consuming ice cream. Kantono et al. (2016) reported that listening to liked music significantly increased HR that in turn was correlated to positive emotions and ratings of ice cream attributes when compared to disliked music. In their study SC increased while listening to disliked music compared to liked music and was correlated to negative emotions and the bitterness of the ice cream. Hence electrophysiology measurements are crucial to help document changes in emotion when consuming food while listening to different sounds and music.

As reported in previous studies, music can influence consumer purchasing behaviour, food selection, and food perception that can further impact the flavour perception of food through the emotions it elicits. The

viewing of food, in turn, has been shown to evoke emotions that can influence music selection and electrophysiological responses. To date, there have been no studies reporting on how music varying in liking can influence food selection when presented visually. Hence, the objective of this research is to explore how listening to music varying in liking while viewing food can influence hunger levels, liking, and overall satisfaction. In addition, subjective and objective measurements of emotion will be obtained to understand how music influences hunger and food liking. It is hypothesised that music varying in liking will evoke emotions that can influence hunger levels, liking, and satisfaction of food items when viewed by consumers.

2. Materials and methods

2.1. Ethics statement

The current study has been reviewed and approved by the Auckland University of Technology Human Ethics Committee (AUTEC 19/289). Written consents were completed by all participants prior to taking part in the study.

2.2. Participants

All 50 participants (17 males, 33 females) in this study ($M_{age} = 26.40$ years, SD=6.24 years, $Min = 18$, $Max = 44$) completed the experiment under liked and disliked music conditions, as well as during a control condition (i.e., silence). As there was no preliminary data available for these experiments, a standardized effect size was used for the power analysis. For this study, the aim was to detect a relevant effect size with a Cohen's d calculation of 0.80. A power analysis using the ANOVA multi sample group was used in this study, applying a correction for three comparisons, an alpha value of 0.05, and a statistical power of 0.80. From this analysis, it was determined that a sample size of 36 participants in each condition would be required (Cohen, 1988; Primer, 1992). The Dutch Eating Behaviour Questionnaire (DEBQ; van Strien et al., 1986) were examined to assess external eating, emotional eating, and restrained eating. Participants were recruited by advertisements placed around the university and rewarded with supermarket vouchers upon completion of the experiments. Participants were excluded if they smoked, had existing health problems, food allergies, or special dietary preferences. Participants were required to have breakfast but were asked to refrain from eating for at least one hour before the experiment.

2.3. Food stimuli

A fixed lunch meal was prepared by the researcher and viewed by all participants. The lunch meal consisted of fried chicken and a cheeseburger (138.52 g, 1,689.944 KJ), chunky chocolate chip cookies (100 g, 1980 KJ), chocolate fudge brownie (80 g, 1128 KJ), a fresh chicken salad with tomatoes and cucumber (150 g, 458.25 KJ), mandarins (80 g, 134.40KJ), green grapes (80 g, 216 KJ), and a banana (80 g, 344.80 KJ). The amount energy contained in the fixed meal was approximately 5951.394 KJ in total. These values were converted to energy (kJ) based on the nutritional information published on the McDonald's New Zealand (www.mcdonalds.co.nz) and Mrs Higgins (https://www.mrshiggins.com/products) websites, as well as the NZ Food Composition Data for Nutrition Information (New Zealand Institute of Plant and Food Research, 2018) (https://www.foodcomposition.co.nz/downloads/concise-13-edition.pdf).

2.4. Music selection

Participants were asked to create a music playlist based on individual liking (Balasubramanian et al., 2018; Liljeström et al., 2013). The selected music was rated using an unstructured 10 cm line scale anchored with "extremely dislike" and "extremely like". Three liked and three disliked songs were chosen by each participant. The music was accessed through Spotify and played through a Sennheiser headset (Series HD 518: Sennheiser Electronics GmbH and Co. KG, Wademark, Germany). Participants listened to their liked and disliked music while viewing the food.

2.5. BMI

The body mass index (BMI, kg/m^2) and waist circumference of each participant were determined because the physiological and behavioural responses to satiety, appetite, and hunger between lean, over-weight, and obese individuals are likely to be different (Dalton et al., 2013).

2.6. Dutch eating behaviour questionnaire (DEBQ)

Participants were asked to complete the Dutch Eating Behaviour Questionnaire (DEBQ) before being invited to participate in the sensory experiment. The questionnaire was completed by participants at home and aimed to identify their level of restraint, emotional eating, and external eating (van Strien et al., 1986). Participants answered the questionnaire by selecting the attributes that best matched their opinion and perspective. Each question item in the questionnaire was rated using a 5-point Likert scale ranging from "never" to "very often". The questionnaire provided total scores for three different traits: restrained, emotional, and external eating. Data was obtained using the Qualtrics software (Qualtrics, Ohio).

2.7. Self-reported emotion

Self-report emotions were selected using the Check All That Apply (CATA) method (Ng et al., 2013). Table 1 lists the twenty emotions identified by a focus group of thirty participants when viewing the lunch meal. The list of emotional responses of participants were determined while viewing a real lunch meal under different music conditions. All emotional response data was acquired using an online questionnaire (Qualtrics, Ohio). Definitions of the emotions were provided to the participants to ensure the meanings of the emotion terms were understood.

Table 1
Description of emotions used in this study.

Emotion attributes	Description
Positive	A positive experience, situation, or result
Active	Engaging or ready to engage in physically energetic pursuits
At easy	Showing or involving great activity or vitality
Interested	Having an interest or involvement; not impartial
Satisfied	Peaceful, happiness or calm feeling when an outcome is above expectations
Excited	Very enthusiastic and eager
Relaxed	Free from tension and anxiety
Calm	Not showing or feeling nervousness, anger, or other strong emotions
Joy	A feeling of great pleasure and happiness
Pleasure	A feeling of happy, satisfaction, and enjoyment.
Happy	Feeling or showing pleasure or contentment
Amazed	Surprise (someone) greatly; filled with astonishment.
Tired	In need of sleep or rest
Alone	Having no one else present.
Drowsy	Sleepy and lethargic; half asleep
Boredom	The state of feeling bored.
Tense	In or of a state of physical or nervous tension
Dissatisfied	Not content or happy with something.
Exhausted	Very tired
Contempt	The feeling that a person or a thing is worthless or beneath consideration.

2.8. Electrophysiological responses

Monitoring of heart rate (HR), respiratory rate (RESP) and skin conductance (SC) were obtained using a NeXus 10 device and BioTrace software (Mind Media, Netherlands). For SC, electrodes (pre-gelled Ag/AgCl) were positioned on the volar surface of the medial phalanges on the index and middle fingers of the non-dominant hand, following cleansing with an exfoliating agent and an alcohol swab. HR were recorded with the Nexus-10-Heart Rate sensor attached to the left index finger using the photoplethysmography technique.

Initially, electrophysiological measurements were carried for five minutes to establish baseline readings under a quiet condition. Following this, measurements were obtained for three minutes in the liked music, disliked music, and silent conditions without viewing a real lunch meal. Subsequently, a fixed variety of lunch food items were served, and electrophysiological measurements were once again obtained for 3 min, this time under either silent or music conditions while participants viewed the lunch food items. During this experiment, participants were instructed to sit upright in a relaxed position and to keep their non-dominant hand still.

Electrophysiological responses were measured according to Kantono et al. (2019) and Xu et al. (2019). The duration was chosen as phasic electrodermal measures typically peak around 2–5 s after stimulus delivery with recovery occurring after 30 s. The rate of recovery is dependent upon participant's emotion state. The HR signals were recorded at 128 samples per second and SC at a rate 32 samples per second. In addition, RESP was estimated using a respiration belt placed on the navel.

2.9. Satiety and liking of appearance

Visual analogue scales (VAS) were used to measure hunger, desire to eat, fullness, satiability, and food pleasantness both before and after the meal (Flint, 2000). While viewing the lunch meal participants rated these measures using a 10 cm visual analogue scale with words anchored from 0 (Not at all) to 10 (Extremely) before and after listening to music.

2.10. Liking and satisfaction measures of food items

After viewing food under silent and music conditions, participants rated overall liking and satisfaction (Andersson et al., 2012) of lunch food items. Liking and satisfaction of food items were rated using a 10 cm unstructured line scale anchored from 0 (Dislike extremely) to 10 (Like extremely) and from 0 (Not at all satisfied) to 10 (Extremely satisfied), respectively.

2.11. Experimental procedure

Fig. 1 provides an overview of the experiment carried out in this study. Participants were required to have breakfast, and refrain from eating for at least one hour before the start of experiment. The study was carried out between the hours of 11:00 am and 3:00 pm to ensure that all participants completed the experiment during lunch time. On arrival at the laboratory the participants had their weight, height, and waist circumference recorded, and then ratings of hunger, fullness, and desire to eat were determined using Visual Analogue Scales. Subsequently, electrophysiological measurements of Heart Rate (HR), Skin Conductance (SC), and Respiration Rate (RESP) were obtained under liked, disliked music, and silent conditions.

Three different measurements were collected in this study, which took up to sixteen minutes to complete. For the first five minutes, baseline electrophysiological measures were obtained while the participants were seated in the laboratory under the silent condition. Subsequently, measurements were taken for three minutes without viewing a real lunch meal in the liked music, disliked music, and silent conditions. Baseline electrophysiological measures were obtained for the first five minutes while the participants were seated in the laboratory under the silent condition. Next, a fixed variety of lunch food items were served, and electrophysiological measurements were further obtained for three minutes under the silent and music conditions, while viewing the lunch items. Then participants selected the emotions they experienced from a check all that apply (CATA) list provided (Table 1). Hunger, fullness, desire to eat, pleasantness, food overall liking, and food satisfaction were also measured after viewing the lunch meal. There were compulsory five-minute breaks between emotion measures, electrophysiological measures, and questionnaire completion. A repeated-measures design was employed. The three separate conditions (control, liked music, and disliked music) were randomised and performed within a maximum of seven days between each condition. Each participant visited the laboratory three times, with the three conditions being randomised and performed within a maximum of seven days between each session. All sessions took place at the same time and day of the week.

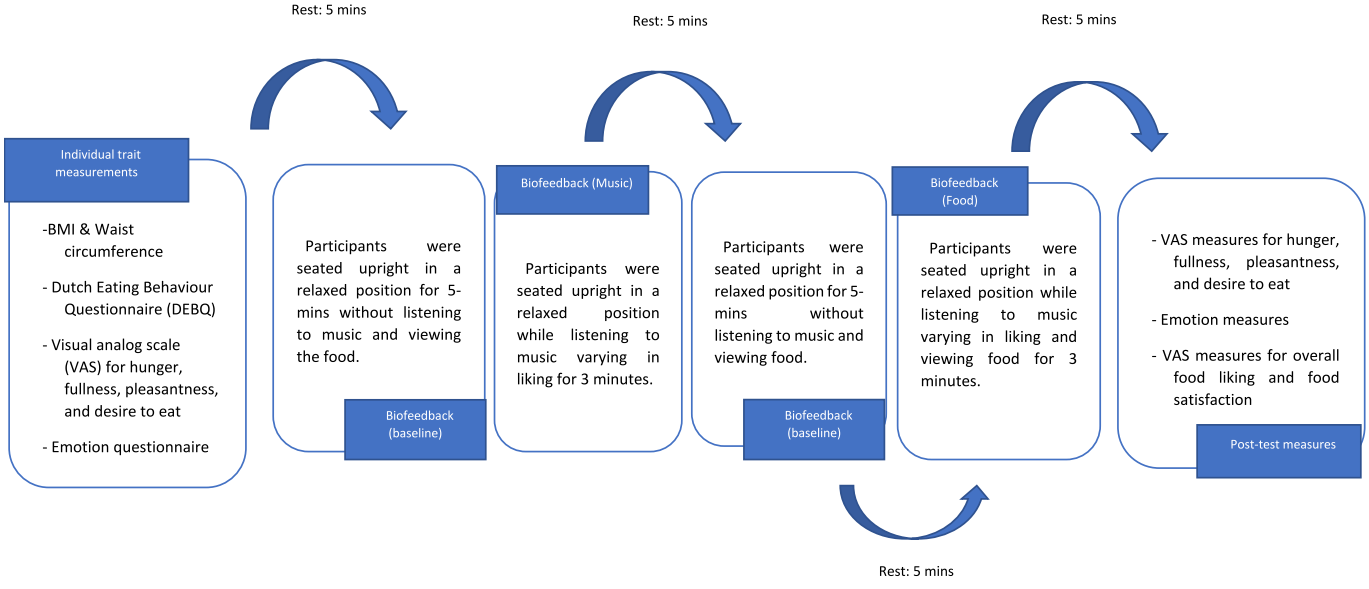


Fig. 1. Overview of the experiment.

2.12. Statistical analysis

For the DEBQ results, average values were computed for each eating behaviour dimension, including restraint, emotional and external eating. The emotion data obtained using CATA was dichotomised into two categories (0 = not selected / 1 = selected), and the frequencies of emotional responses under different music conditions were determined. Multiple pairwise comparisons were conducted using the Marascuilo procedure for results that reached statistical significance ($\alpha = 0.05$).

A mixed model ANOVA was carried out to investigate if there were significant differences in the percentage change in electrophysiological measures while participants viewed real food under different music and silent conditions. A total score for hunger was calculated by summing the scores for hunger, fullness (reversed scoring), and desire to eat. Post-average liking scores were obtained by averaging the scores for a meal in terms of appearance and enjoyment. Post-average food liking and satisfaction values were obtained by averaging the scores for healthy and unhealthy food items. Differences between music and silent conditions in terms of hunger, fullness, desire to eat, liking of appearance, enjoyment, food liking and satisfaction measures were analysed using a mixed model Analysis of Variance (ANOVA). Post hoc Tukey's Honestly Significant Difference (HSD) test was applied if statistical significance was observed ($p < 0.05$). Partial eta squared was reported as a measure of effect size (Cohen, 1988; small = 0.01; medium = 0.06; large = 0.14).

Furthermore, a two-way ANOVA was carried out to explore how the dependent variables of liking of appearance, enjoyment, food liking, and satisfaction were influenced by different music and silent conditions, while controlling for the other covariates such as physical characteristics (BMI, waist circumference, age, and gender) and psychological traits (DEBQ). Partial least square regression (PLSR) was carried out to summarize the relationship between two datasets: i) ratings of hunger, fullness, desire to eat, food pleasantness, food overall liking, and food satisfaction, and ii) the three electrophysiological measures obtained from participants who viewed the food under silent and the two music conditions. Multiple Factor Analysis (MFA) was used to understand the collective effect of music on both electrophysiological measures and emotions, and how they were related to food liking, enjoyment, and satisfaction measures. All statistical analysis were performed using XLSTAT (Version 2021.5) (Lumivero, USA).

3. Results

3.1. Physical and psychological characteristics

Participants had a mean age of 26.4 ± 6.24 years. Male and female participants had an average BMI and waist circumference of 26.19 ± 0.65 kg/m^2 and 94.98 ± 3.52 cm, and 22.58 ± 0.62 kg/m^2 and 78.28 ± 1.97 cm, respectively. On average, the DEBQ scores for dietary restraint, emotional eating, and external eating scores were 2.742 ± 0.91, 2.533 ±1.000, and 3.354 ± 0.729, respectively.

The difference in hunger, food appearance, enjoyment, overall liking, and satisfaction ratings between physical (gender, age, and BMI) and psychological (DEBQ dimension) characteristics were assigned as covariates in this study. There were no significant differences across gender, age, or BMI for the silent, liked music, and disliked music conditions (all $p > 0.1$). In addition, the DEBQ dimensions (restraint, emotional, and external eating) did not influence hunger, food appearance, enjoyment, overall liking, and satisfaction.

3.2. Effects of music on ratings of hunger and the desire to eat while viewing a meal

Ratings of hunger ($F_{(51,149)} = 0.470$, $p = 0.761$, partial eta squared = 0.42), desire to eat ($F_{(51,149)} = 1.205$, $p = 0.214$, partial eta squared = 0.39), and fullness ($F_{(51,149)} = 0.813$, $p = 0.790$, partial eta squared = 0.30) did not significantly differ across the silent condition and the liked and disliked music conditions before viewing food. This result indicated that the participants' appetite was equivalent across the three different conditions before subsequent measures of hunger were obtained after looking at the food (Hetherington et al., 2006; Long et al., 2011; Oldham-Cooper et al., 2011).

When viewing the food (Table 2), there was a significantly higher rating of hunger ($F_{(51,\ 149)} = 1.653$, $p = 0.017$, partial eta squared = 0.46) while listening to disliked music compared to liked music or silence. There were no significant differences between music or silent conditions in terms of the desire to eat ($F_{(51,\ 149)} = 1.217$, $p = 0.\ 202$, partial eta squared = 0.39) and fullness ($F_{(51,\ 149)} = 0.893$, $p = 0.688$, partial eta squared = 0.32) ratings.

3.3. Effect of music on liking of appearance and enjoyment of food

Liking of appearance ($F_{(2,149)} = 5.29$, $p = 0.007$, partial eta squared = 0.44), and enjoyment ($F_{(2,149)} = 15.57$, $p < 0.0001$, partial eta squared = 0.50) were significantly lower when listening to disliked music compared to liked music or silent condition (Table 2).

3.4. Effect of music on liking and satisfaction of healthy and unhealthy food items

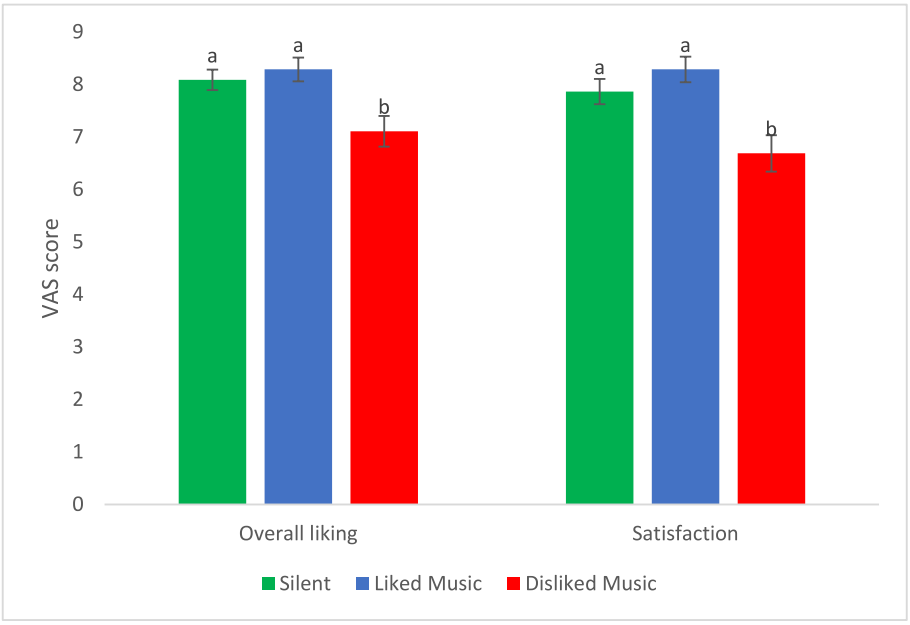
The effect of music had significant effects on overall food liking ($F_{(51,149)} = 2.333$, $p = 0.000$, partial eta squared = 0.55) and food satisfaction ($F_{(51,149)} = 2.908$, $p < 0.0001$, partial eta squared = 0.60) ratings (see Fig. 2a). Overall liking and satisfaction ratings were significantly lower when viewing food while listening to disliked music compared to liked music and silent conditions.

The study also analysed the effect of music on food liking and satisfaction of food items by using a mixed model ANOVA. As seen in Fig. 2b, liking and satisfaction of seven food items immediately after viewing the food varied under the different music conditions. Healthy food items including salad ($F_{(51,149)} = 2.390$, $p = 0.000$, partial eta squared = 0.55), a banana ($F_{(51,149)} = 2.450$, $p < 0.0001$, partial eta squared = 0.56), an orange ($F_{(51,149)} = 1.804$, $p = 0.006$, partial eta squared = 0.48), and grapes ($F_{(51,149)} = 1.724$, $p = 0.011$, partial eta squared = 0.47) had significantly lower liking scores under the disliked music condition compared to the silent and liked music conditions. In terms of food satisfaction, healthy food items including salad ($F_{(51,149)} = 3.392$, $p < 0.0001$, partial eta squared = 0.64), a banana ($F_{(51,149)} = 2.819$, $p < 0.0001$, partial eta squared = 0.59), an orange ($F_{(51,149)} = 2.193$, $p = 0.000$, partial eta squared = 0.53), and grapes ($F_{(51,149)} = 1.771$, $p = 0.008$, partial eta squared = 0.48), as well as an unhealthy food item, a chicken burger ($F_{(51,149)} = 2.700$, $p < 0.0001$, partial eta squared = 0.58), all received significantly lower satisfaction scores when participants viewed the lunch meal under the disliked music

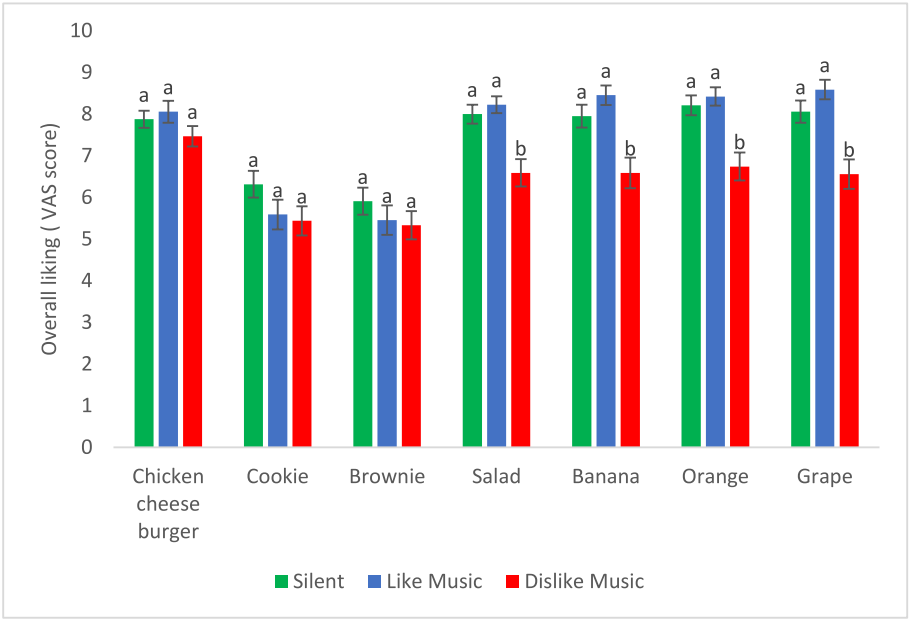
Table 2
Ratings of different measures while viewing a meal under silent (control), as well as liked and disliked music conditions. The results are expressed as mean ± standard error (SE). Different superscripts [a, b] indicate significant differences at $p < 0.05$.

	Silent	Liked Music	Disliked Music	p-value (df = 51, 149)
Pre-Hunger	5.94 ± 0.214^{a}	5.86 ± 0.190^{a}	5.88 ± 0.173^{a}	0.761
Post-Hunger	6.940 ± 0.267^{b}	7.620 ± 0.254^{ab}	7.840 ± 0.240^{a}	0.017
Fullness	2.320 ± 0.300^{a}	2.040 ± 0.264^{a}	1.978 ± 0.277^{a}	0.668
Desire to eat	7.890 ± 0,243^{a}	7.610 ± 0.255^{a}	7.440 ± 0.265^{a}	0.427
Liking of appearance	8.040 ± 0,234^{a}	8140 ± 0.232^{a}	7.180 ± 0.263^{b}	0.007
Enjoyment	8.280 ± 0.212^{a}	8.140 ± 0.232^{a}	6.780 ± 0.229^{b}	<0.0001

A)



B)



C)

Fig. 2. Ratings obtained while looking at a meal during silent (control), liked or disliked music conditions. The results are expressed as mean ± standard error (SE). Different superscripts (a, b) indicate significant differences at $p < 0.05$. (A) Overall liking and satisfaction of a lunch meal; (B) Overall liking of unhealthy (chicken cheeseburger, cookie, and brownie) and healthy (salad, banana, orange, and grapes) lunch food items; (C) Satisfaction of unhealthy and healthy lunch food items. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

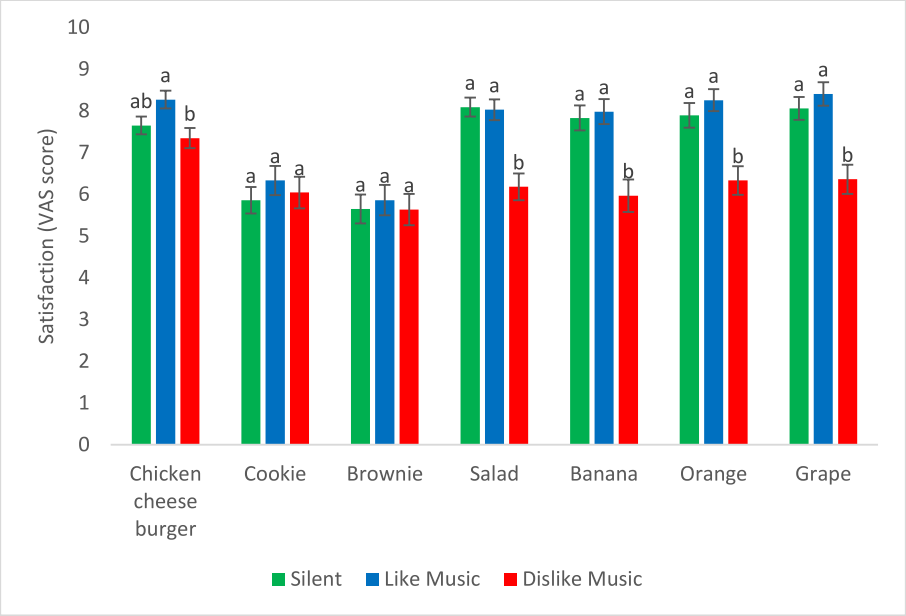


Fig. 2. (*continued*).

Table 3
Cosine values obtained by Correspondence Analysis that show the correlation between check-all-that apply (CATA) emotion attributes under silent and music (liked and disliked music) conditions when viewing a lunch meal. Values highlighted in green and red indicate high positive and negative correlations, respectively.

Emotion	Silent	Liked Music	Disliked Music
Tired(-)	-0.996	-0.152	0.906
Alone(-)	-0.847	-0.588	0.999
Tense(-)	-0.933	-0.424	0.988
Boredom(-)	0.306	-0.929	0.208
Dissatisfied(-)	-0.865	-0.560	1.000
Drowsy(-)	-0.790	-0.665	0.990
Exhausted(-)	-0.994	-0.176	0.916
Contempt(-)	-0.892	-0.513	0.999
Calm(+)	0.939	0.408	-0.986
Interested(+)	0.999	0.034	-0.849
Relaxed(+)	0.575	0.856	-0.906
Excited(+)	0.707	0.754	-0.965
Pleasure(+)	0.133	-0.980	0.378
At ease(+)	0.990	-0.076	-0.786
Happy(+)	0.188	0.993	-0.653
Active(+)	0.533	-0.807	-0.041
Joy(+)	-0.747	0.612	0.317
Amazed(+)	0.916	-0.337	-0.595
Satisfied(+)	0.952	0.371	-0.978
Positive(+)	0.553	0.869	-0.895

condition compared to the liked music and silent conditions.

3.5. Emotions during different music conditions when viewing foods

Multidimensional alignment (MDA) was applied to determine the cosine values between the emotions cited when viewing the foods under the silent condition (control), as well as the liked and disliked music conditions. Table 3 highlights the emotions which are correlated with the control and music conditions using the first two dimensions of the Correspondence Analysis (CA) bi-dimensional map. Cosine values greater than 0.707 (Carr et al., 2009) suggest a strong relationship between music conditions and the emotion attributes.

Viewing of the food in the silent condition positively correlated with emotions of calm, interest, feeling at ease, amazement, and satisfaction. Listening to liked music conditions were further positively correlated with positive emotions such as relaxed, excited, happy, and positive. However, viewing food under the disliked music condition was positively correlated with the negative emotions of tiredness, loneliness, tenseness, dissatisfaction, drowsiness, exhaustion, and contempt.

3.6. Physiological responses to musical stimuli

A mixed-model ANOVA was significant for the effect of viewing a lunch meal during the silent condition (control) as well as the liked and disliked music conditions. The electrophysiological responses between the three conditions while viewing a meal revealed that SC, HR, and RESP were significantly different. HR ($F_{(2,149)} = 2.451$, $p < 0.0001$, partial eta squared = 0.94) was significantly higher when viewing food under the silent condition compared to liked and disliked music conditions. However, SC ($F_{(2,149)} = 1.582$, $p < 0.0001$, partial eta squared = 0.98) and RESP ($F_{(2,149)} = 0.776$, $p < 0.0001$, partial eta squared = 0.98) measures were significantly higher when viewing food while listening to disliked music compared to liked music and the silent condition (Fig. 3).

3.7. Partial least squares regression

Partial least squares regression analysis was carried out to demonstrate the relationship between the three electrophysiological measures and ratings of appetite, liking and satisfaction under all three sound conditions (Fig. 4). SC and RESP were both found to be positively correlated with hunger, and negatively with ratings of enjoyment. HR was found to be positively associate with ratings of enjoyment, however, it was negatively correlated with ratings of hunger.

3.8. The overall relationship between emotional response, electrophysiological measures, appetite, pleasantness rating, food liking, and satisfaction, while participants viewed a lunch meal under different sound conditions

Fig. 5 illustrates the MFA biplot showing the relationship between participants' emotional response, electrophysiological measures, rated appetite (hunger, fullness, and desire to eat), and hedonic measures (liking of food appearance, food overall liking, and satisfaction) as a function of sound condition. The first (F1) and second (F2) dimensions of the MFA accounted for 76.45 % and 23.55 % of the variance in the data, respectively (Fig. 5). Viewing the meal under silent and liked music conditions had high positive scores along F1 that were associated with fullness, desire to eat, liking of appearance, food overall liking, and food satisfaction, as well as the positive emotions of calm (+), interested (+), relaxed (+), excited (+), at ease (+), satisfied (+), and positive (+) attributes. Viewing the meal under either the silent and liked music conditions was associated with the electrophysiology measures of HR. In contrast, viewing the lunch meal while listening to disliked music had a high negative score along F1 that was associated with higher ratings of hunger, and negative emotions such as tired (−), alone (−), tense (−), drowsy (−), exhausted (−), and contempt (−), as well as the electrophysiology measures of SC and RESP.

4. Discussion

4.1. Ratings of hunger were significantly higher when participants listened to disliked music while viewing a meal

It is widely recognised that humans tend to "eat with their eyes first", a phenomenon known as "visual hunger". This concept suggests that the act of looking at food could be an evolutionary adaptation, where our brains have learned to take pleasure in seeing food, as it often precedes

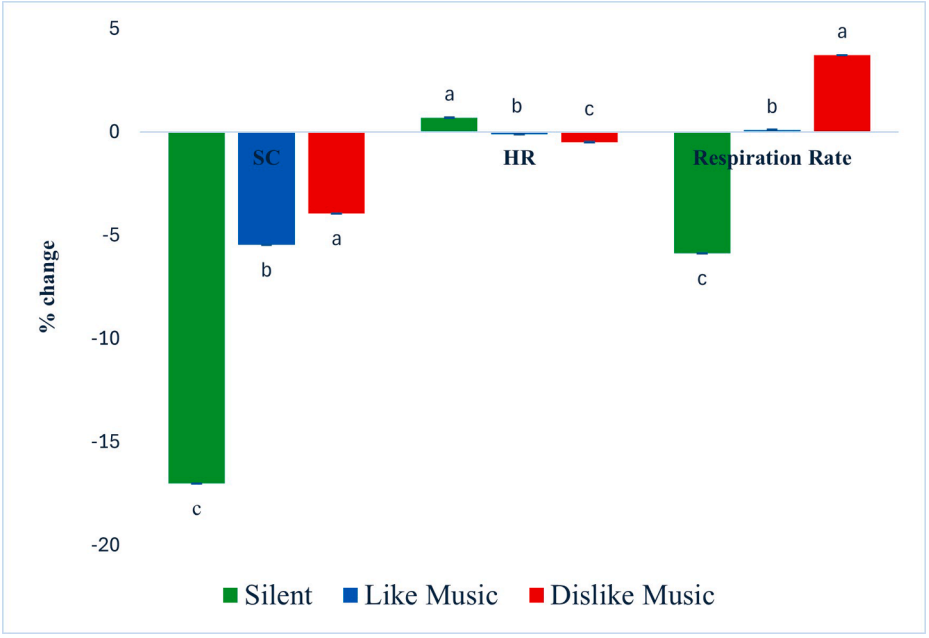


Fig. 3. Percentage change (baseline) in skin conductance (SC), heart rate (HR), and respiratory rate (RESP). [a,b,c] Different superscripts indicate significant changes in electrophysiological measures ($p < 0.05$). The error bars reflect the standard error of electrophysiological measurements for each of the music conditions.

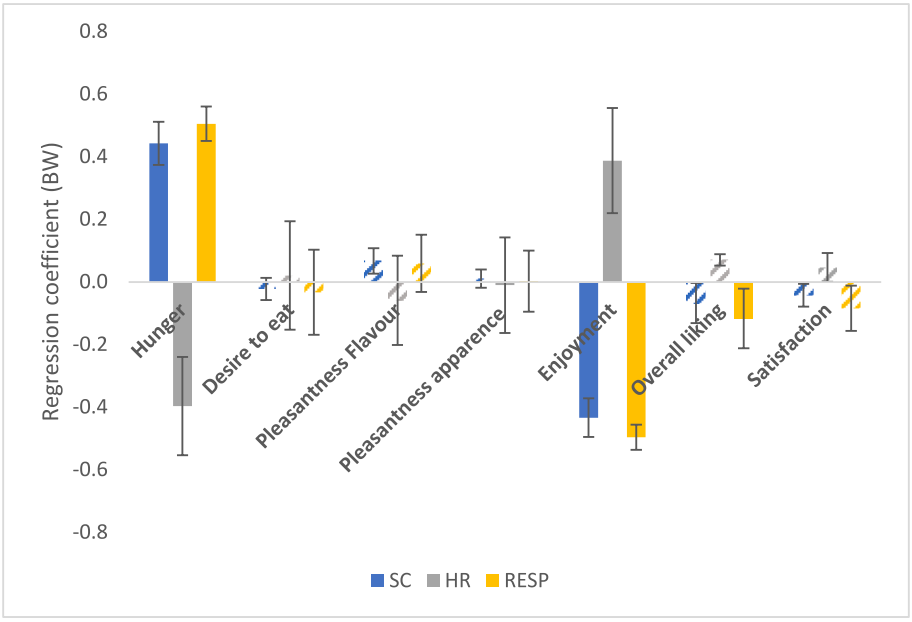


Fig. 4. Standardised regression coefficients between physiological measure and different measures using partial least squares regression analysis. Filled bars indicate significant regression coefficients.

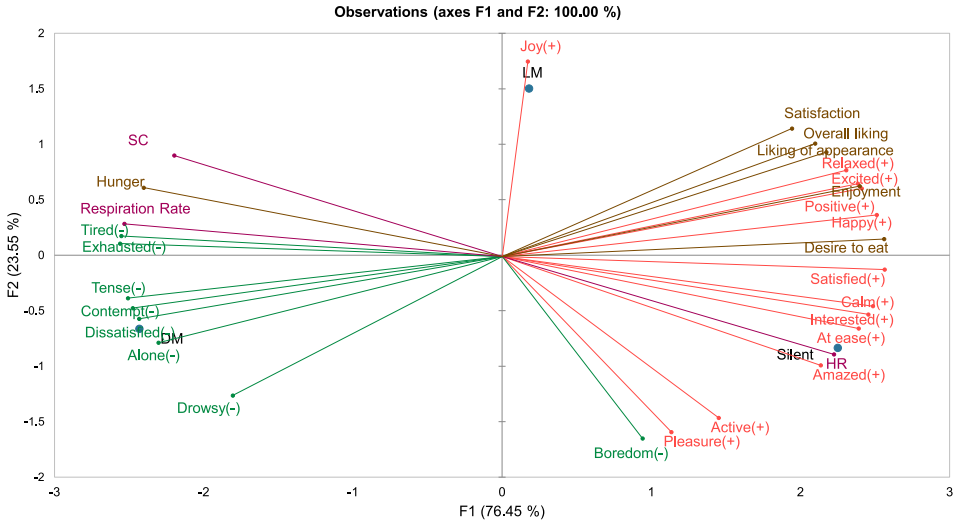


Fig. 5. Multiple Factor Analysis (MFA) bi-plot showing changes in positive emotions (green), negative emotions (red), electrophysiology responses including skin conductance (SC), heart rate (HR), and respiration rate (RESP) (purple), as well as food ratings (brown) that include hunger, fullness, desire to eat, liking of appearance, food overall liking, and food satisfaction, while participants viewed a meal under silent, liked music (LM), and disliked music (DM) conditions. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

consumption. The automatic reward associated with the sight of food likely signalled the possibility of obtaining necessary nutrients for survival, and at the same time, physiological responses would prepare our bodies to receive sustenance (Spence, 2016). In this study, hunger was found to be significantly higher when participants listened to disliked music compared to liked music or silent conditions. However, ratings of fullness and desire to eat were not significantly different. The impact of music on ethnic food selection while viewing a menu was investigated by Muniz et al. (2017). They found that participants were hungrier at the end of the study under all music-listening conditions. However, the study did not examine how music impacted hunger level following the viewing of a food menu. According to Bhanumathi (2021), hunger is controlled by the satiety and pleasure centres of the brain, indicating a close relationship between basic and emotional motivations.

The current study supports the notion that the effect of music on hunger may depend on the individual's subjective liking of the music. Previous studies have shown that music, when varying in liking, can evoke emotions and influence food perception. For example, Kantono et al. (2016) reported that listening to liked music evoked positive emotions and increased pleasantness ratings of chocolate ice cream. Similarly, a study by Lin et al. (2022) demonstrated that participants experienced positive emotions when listening to liked music. Therefore, when investigating the impact of music on consumer food behaviour, future research should pay closer attention to the effects of music that vary in liking, particularly self-selected music. This could provide valuable insights into the specific mechanisms through which music influences hunger ratings and other food-related responses.

The differences in fullness and desire to eat between different music conditions were also examined in this study. There was no significant difference under silent, liked and disliked music conditions when

viewing a real food in terms of fullness and desire to eat. This finding seemed to be consistent with findings reported by Mathiesen et al. (2022). The researchers showed that the effect of music type at home was not significantly different in terms of desire to eat while viewing comfort food pictures (pasta), while listening to music outside (e.g. restaurant) significantly increased the desire to eat comfort food. This suggests that music alone may not be enough to influence the desire to eat food while viewing pictures. The combination of music and the eating environment may have a greater impact on food desirability (Papies et al., 2021; Papies et al., 2022). There are studies that have shown a significant difference in the impact of music on the rating of hunger when viewing food. Brunstrom and Shakeshaft (2009) explored the effect of expected satiety, food liking, and food-specific restraint on prospective portion size (the amount of food that is needed in order to bring about meal termination) and food reward (the amount participants were prepared to pay per kcal). Participants in the study were shown pictures of eight different snack foods that depicted increasing portion sizes of each food. The study found that foods perceived as having high expected satiety were considered more rewarding and were selected in smaller portions. Likewise, rewarding foods were chosen in smaller portion sizes on a calorie-per-calorie basis. Liking was identified as a stronger predictor of prospective portion size compared to restraint. This suggests that people tend to consume more of the foods they like and less of those they dislike, indicating a natural association between liking and prospective portion size. Additionally, the study revealed variations in expected satiety across different foods, with crackers expected to provide higher satiety per calorie compared to chocolate M&M's. This indicates that our expectations of satiety can be influenced by the characteristics of the stimuli we encounter, including our liking for them. Therefore, if someone enjoys listening to a particular type of music, it is possible that their liking for the music could enhance their expectations of satiety, leading them to consume smaller portion sizes.

4.2. Viewing a meal during the liked music and silent conditions increased hedonic ratings of the food

Viewing the lunch meal while listening to the liked music condition or in silence increased overall liking ratings compared to the disliked music condition. Previous studies have mainly focused on the impact of music on food enjoyment post-consumption. For instance, Fiegel et al. (2014) found that participants rated chocolate higher when listening to jazz music compared to hip-hop and rock. Similarly, Alamir et al. (2020) observed increased liking for a dish comprising a falafel sandwich and fruit skewers when accompanied by relaxing music rather than restaurant noise or traffic sounds. Limited research has explored how music influences food liking during visual exposure to the food. Jing et al. (2024) demonstrated that listening to classical music significantly increased liking ratings for sweet food images compared to rock, jazz, and hip-hop music. The harmonious elements of classical music, such as higher tones and softer rhythms, may resonate with the concept of sweetness, thereby influencing food preferences (Knöferle & Spence, 2012). In the current research, viewing the lunch meal while listening to the liked music condition or in silence increased overall liking ratings compared to the disliked music condition. I Understanding how music affects food liking when viewing the food is important as this knowledge can be used to create more pleasurable and enjoyable dining experiences for consumers.

4.3. Viewing the meal during the liked music and silent conditions increased satisfaction and enjoyment of food

In this study, listening to liked music or being in a silent environment significantly increased enjoyment and satisfaction of the lunch meal. This is in line with studies that show listening to music can enhance consumers' pleasure and satisfaction, extend store visits, and increase purchases (Morrison et al., 2011; North et al., 2000). Additionally, gender may influence the effects of music on consumers' moods (Andersson et al., 2012). This suggests a potential interaction between gender and music in terms of arousal, with females showing more excitement than males in the no-music condition. The current study provides evidence that both silent and preferred music conditions can enhance hedonic responses to visually presented food. This finding highlights the potential impact of the auditory environment on food liking, emphasising the influential role that music can play in enhancing overall enjoyment and satisfaction during a dining experience.

4.4. Liked music and silent conditions increased ratings of overall liking and satisfaction of healthy food items when participants viewed food

The presence of liked music or silence while viewing a lunch meal significantly increased overall liking and satisfaction of healthy food items such as salad, banana, orange, and grapes, compared to the disliked music condition. Hence, there is evidence that music has the potential to influence our liking and satisfaction of foods. Biswas et al. (2018) conducted a study where participants were divided into two groups: one with a "relaxation prime present" and one with a "relaxation prime absent." In the former condition, participants were instructed to reflect on a time when they felt highly relaxed and wrote a detailed essay about it, while participants in the latter condition did not engage in the writing task. The authors found that participants had a greater preference for salad when exposed to low-volume ambient noise (compared to high-volume ambient noise) in the absence of a relaxation prime. In a separate experiment conducted in a supermarket, the authors found that playing low-volume ambient music (around 55 dB) led to a higher proportion of healthy item purchases compared to high-volume ambient music (around 70 dB), which resulted in a higher proportion of unhealthy item purchases. This suggests that experiencing increased relaxation from listening to low volume ambient music can lead to making more healthful food choices. Huang and Labroo (2019) further reported that listening to low pitched music rated as unfamiliar, discomforting, slow tempo, and unpleasant led to an increased selection of unhealthy food items, including higher calorie foods like cheesecake, compared to high pitched music rated as familiar, comforting, fast tempo, and pleasant. These findings add to the evidence that the pleasantness of music can lead to the selection of more healthy food items. Hence, it can be inferred that music, by evoking positive emotions, can lead to the choice of more healthy food items.

4.5. Liked music and silence evoked positive emotions, and increased heart rate that may be related to increased liking, enjoyment, and satisfaction of viewed food

The complex interplay between music and food can be better understood by examining both subjective (i.e., emotions) and objective (i.e., physiological) measures. In this study, viewing food under liked music or silent conditions was linked to positive emotional states (Appendix A.4) compared to disliked music. In the literature, inconsistent findings have been reported regarding how background music influences people's mood. Demoulin (2011) found that music congruency, particularly with low arousal songs, increased pleasantness, and elicited feelings of calmness and relaxation in a restaurant setting compared to highly arousing music. Similarly, our current study found that positive emotions were linked to significantly increased ratings of liking, enjoyment, and satisfaction when viewing food under the silent and liked music conditions compared to the disliked music condition. Furthermore, prior studies have identified that liked background music playing at 55 dB SPL increased the sale of healthy food items by inducing relaxation, while at 70 dB SPL the music increased the sale of unhealthy food items that induced excitement (Biswas et al., 2018). Another study reported that listening to classical music significantly elicited more feelings of positivity and calmness, leading to a higher preference for both healthy (e.g., low-fat milk) and indulgent (e.g., milk chocolate)

food options compared to rock/metal and hip-hop music (Motoki et al., 2022).

Our study utilised the framework from the Mehrabian Russel (M−R) model to assess the concept of how environmental stimuli may impact affective states (valence, arousal, and dominance) that subsequently influence approach or avoidance behaviours. In this study, when viewing food under liked music, higher HR levels were observed compared to when viewing food under the disliked music condition. Additionally, positive emotions were found to be correlated with increases in HR. Lynar et al.,(2017) demonstrated that self-selected music was associated with higher ratings of positive emotions (e.g., joy and engagement) that in turn were associated with increases in HR. Similarly, Kantono et al. (2016) reported that listening to liked music significantly increased HR that was further correlated to positive emotions compared to listening to disliked music.

This study revealed that viewing food in the silent condition was linked to higher heart rate (HR) in comparison to listening to disliked music. Moreover, we found that positive emotions were correlated with increases in HR. The findings are in line with the research conducted by Lui and Grunberg (2017), which provide evidence that silent condition can increase rumination, cognitive arousal, and physiological arousal, with longer periods of silence inducing greater sympathetic response. Thus, findings of our study suggests that non-distressing sounds may be more effective in inducing relaxation than a silent condition. Furthermore, our study explored how the valence dimension (i.e. liked / disliked music) can impact mood, in turn influencing consumer behaviour (ratings of liking, enjoyment, satisfaction). However, it is important to note that other affective dimensions such as arousal can also influence consumer consumption behaviour (Andersson et al., 2012), and future studies should consider including other affective dimensions like arousal and dominance in their research.

4.6. Limitations and future directions

The current study was constrained by its laboratory setting for viewing food, and it would be valuable for future research to investigate the impact of self-selected music on food choices in real-world environments, such as food courts. This is important because understanding how music influences food choices in natural settings can provide insights that are more representative of everyday decision-making processes. Another limitation is that this study did not investigate the effect of music type, tempo, ethnic on food choices. The effect of music type and tempo can impact food choices (Caldwell et al., 2002; Feinstein et al., 2010; Zellner, 2014). Further research should explore the interaction of food and music in real-world settings using additional music stimuli. Additionally, the participants were recruited from New Zealand and the specific foods used were representative of their cultural context, potentially limiting the generalisability of the results to other population groups (Wanich et al., 2018). Furthermore, this study had a small number of male participants (N=17), which may limit the ability to test for differences between male and female participants (Dickinson et al., 2012; Dieze et al., 2017). Finally, a limitation of this study was that emotional measurements were only carried out at the end of the food viewing period, providing limited insights into the temporal effects of listening to music on food choices (de Wijk et al., 2012; Kaneko et al., 2018).

5. Conclusion

This present study aimed to investigate the impact of music varying in liking on emotions, hedonic liking, and electrophysiological measurements while viewing a meal. The findings revealed that participants rated healthy food items higher for overall liking and satisfaction when listening to liked music compared to silent and disliked music conditions. In contrast, the disliked music condition elicited negative emotions, changes in skin conductance and respiration rate, while were also associated with higher hunger scores. Conversely, the silent and liked music conditions evoked positive emotions that increased HR, potentially influencing liking, enjoyment, and satisfaction of viewed food. This research supports the idea that listening to different music conditions while looking at real food have impacted on hunger, as well as ratings of liking, enjoyment and satisfaction by inducing emotion. This research highlights the importance of incorporating objective electrophysiological measures to further understand hunger levels, food liking, and satisfaction among consumers under different music conditions. Such information can have practical applications in real-world food-eating environments to enhance positive emotions during consumption and potentially influence healthier food choices.

CRediT authorship contribution statement

Phatharachanok Siangphloen: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Daniel Shepherd:** Writing – review & editing, Writing – original draft, Supervision, Software, Resources, Project administration, Funding acquisition, Conceptualization. **Kevin Kantono:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Methodology, Formal analysis, Data curation. **Nazimah Hamid:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Funding acquisition, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A

Appendix A1. Participant characteristics, as well as questions on hunger and food pleasantness used in this study

	n = 45
Age (years)	26.667 ± 6.256 (18–41)
BMI (kg/m^2)	23.351 ± 3.535 (15.242—31.055)

(*continued on next page*)

(*continued*)

Waist (cm)	82.936 ± 14.563 (60—116.840)
DEBQ – restraint eating	2.822 ± 0.859 (1—4.300)
DEBQ – emotional eating	2.528 ± 0.999 (1—4.769)
DEBQ – external eating	3.353 ± 0.729 (2 – 5)

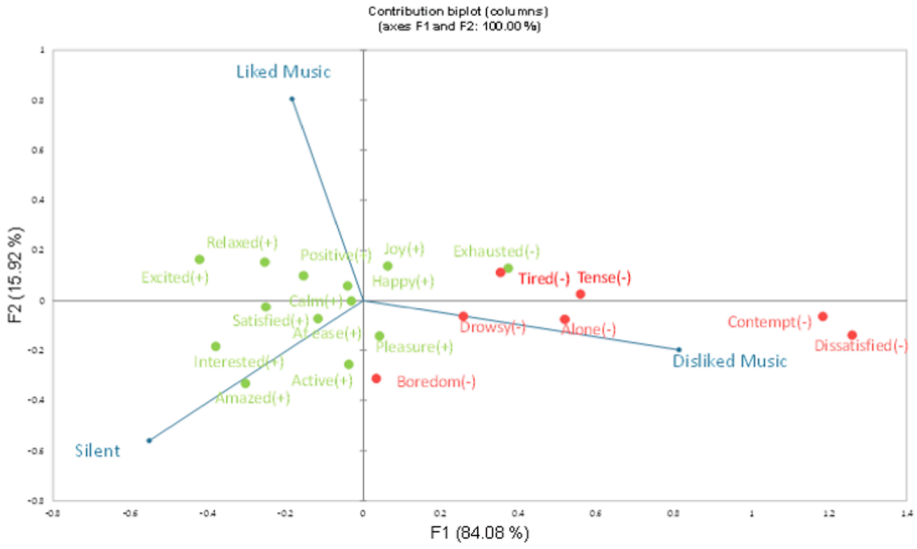
Appendix A2. Satiety questions using the visual analogue scale

Questions	Anchors at each end	Reference
How hungry are you right now?	Not at all hungry and extremely hungry	Kral, Roe & Rolls, 2004
How do you feel?	Not at all full and totally full	Hess, Wang, Kraft & Slavin, 2017
How strong is your desire to eat now?	Very weak and very strong	Lau & Henry, 2017
How much of this food do you think you could consume right now?	Nothing at all and a large amount	Kral, Roe & Rolls, 2004
How satiated do you feel?	I am completely empty and I cannot eat another bite	Hess, Wang, Kraft & Slavin, 2017

Appendix A3. Description and examples of emotion terms used in this study

Emotion attributes		Description
Positive	Positive	A positive experience, situation, result etc is a good one
Active	Positive	Engaging or ready to engage in physically energetic pursuits
At easy	Positive	Showing or involving great activity or vitality
Interested	Positive	Having an interest or involvement; not impartial
Satisfied	Positive	Peaceful, happiness, calm, feeling when an outcome is above expectations
Excited	Positive	Very enthusiastic and eager
Relaxed	Positive	Free from tension and anxiety
Calm	Positive	Not showing or feeling nervousness, anger, or other strong emotions
Joy	Positive	A feeling of great pleasure and happiness
Pleasure	Positive	A feeling of happy satisfaction and enjoyment.
Happy	Positive	Feeling or showing pleasure or contentment
Amazed	Positive	Surprise (someone) greatly; fill with astonishment.
Tired	Negative	In need of sleep or rest
Alone	Negative	Having no one else present.
Drowsy	Negative	Sleepy and lethargic; half asleep
Boredom	Negative	the state of feeling bored.
Tense	Negative	In or of a state of physical or nervous tension
Dissatisfied	Negative	Not content or happy with something.
Exhausted	Negative	Very tired
Contempt	Negative	The feeling that a person or a thing is worthless or beneath consideration.

Appendix A4. Frequency of CATA terms used by panellists to describe the emotion responses and correspondence analysis (CA) results highlighting the differences between music and silent conditions.



The relationship between viewing food under three different music conditions and emotions evoked. The bi-plot included the first two dimensions following Correspondence Analysis. The three different music conditions are labelled in blue font and CATA emotion terms are labelled in green (positive emotions) and red (negative emotions).

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