Food Quality and Preference 136 (2026) 105746

Contents lists available at ScienceDirect

Food Quality and Preference

journal homepage: www.elsevier.com/locate/foodqual

The effect of emotional music on Just-About-Right and speeded-responses to chocolate

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ARTICLE INFO

Keywords:
Chocolate
Music
Multi-sensory experience
Consumer sensory
Contextual cues
Automatic associations

ABSTRACT

Research has demonstrated effects of emotional music on sensory perception of food, with many findings supporting a more favourable evaluation of foods when eaten while listening to positive music over negative emotional music. As the food industry becomes more focused on testing in realistic environments, there is a greater need to investigate the effects of auditory input on consumer perception when captured with measurement tools used in consumer sensory research. Consumers attending an event in New Zealand, took part in a chocolate tasting where they consumed milk or dark chocolate in positive and negative emotional music conditions. Consumer responses included emotional and sensory associations to the samples using a speeded response task, liking and Just-About-Right evaluations. Findings showed liking of dark chocolate was significantly higher in the positive as compared with the negative emotional music condition, whereas sensory changes were restricted to milk chocolate for the sweetness attribute where it was rated as higher in the positive as compared with the negative emotional music condition. Speeded emotional and sensory associations were highly susceptible to the effects of emotional music. Furthermore, exploratory penalty analysis revealed that emotional music can impact consumer feedback on attribute importance. This study builds on current understandings of the effects emotional music can have on automatic consumer responses, specifically speeded self-reported responses and gives further clarity on how the relationship between attributes and their link with liking may change with emotional music. The findings of this study offer a new insight into how emotional music can influence consumer and sensory science study outcomes when speeded self-report and JAR are used.

1. Introduction

1.1. The impact of audio cues on sensory perception of food

A substantial body of research has demonstrated a robust effect of sound on the perception of food. For detailed reviews see Guedes et al. (2023a), Knöferle and Spence (2012) and Spence et al. (2019). These studies have offered interesting insights into the effects of sound on consumer perceptions of the sensory properties of food by investigating factors, such as the affective or emotional characteristics associated with a piece of music and how these can impact the reporting of perceived sensory attributes and taste associations (Barbosa Escobar & Wang, 2024; Guedes et al., 2024; Kantono et al., 2019, 2016; Reinoso-Carvalho et al., 2019, 2020a; Wang et al., 2016). Findings of such studies have been mixed, especially when compared with cross-modal effects, with some results showing that emotional aspects of music have a greater effect than the cross-modal attributes of music on tasting experience (Reinoso-Carvalho et al., 2020b). On the other hand, subsequent research found emotional music to have no significant impact on sweetness, liking and valence responses; whereas, a higher versus lower sweetness soundtrack was found to have significant effects on all these measures (Guedes et al., 2024). Indeed, such cross-modal effects have been found in other studies (Campinho et al., 2023; Guedes et al., 2023a, 2024; Knöferle & Spence, 2012; Wang et al., 2016). Therefore, the current literature provides sufficient evidence to show that audio can and does affect food perception (Crisinel et al., 2012; Guedes et al., 2024; Kantono et al., 2016b; Reinoso-Carvalho et al., 2020a, 2020b; Wang et al., 2020, 2016; Woods et al., 2011). This has been established using rating scales (Crisinel et al., 2012; Guedes et al., 2024; Wang et al., 2020) and using tools particular to sensory and consumer science (Kantono et al., 2019, 2016b; Swahn et al., 2025; Wang et al., 2019). For instance, existing research has found sound conditions can affect the sensory attributes reported as most dominant during consumption (Kantono et al., 2019; Wang et al., 2019). This is

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https://doi.org/10.1016/j.foodqual.2025.105746
Received 27 May 2025; Received in revised form 24 September 2025; Accepted 8 October 2025
Available online 19 October 2025

insightful, given the change to perception that can happen across time when indulging in both music and food.

More recently, researchers have adopted the Just-About-Right (JAR) scale to test cross-modal effects, by including a control, sweet and bitter music condition during the consumption of chocolate ganache at a Swedish food festival (Swahn et al., 2025). However, the penalty analysis did not allow for insight into how the music affected attributes important for liking, as it was carried out for all sound conditions combined. Study findings did suggest liking was significantly different for the higher-sugar ganache, based on music condition, with the control music condition evoking lower liking ratings than the sweet and bitter music conditions. The attributes sweetness and bitterness were also significantly different across sound conditions when looking at the results of both consumed products; for instance, with sweetness receiving significantly higher JAR ratings (further from ideal) when in the sweet sound condition when compared with the control and bitter sound conditions for the higher-sugar ganache (Swahn et al., 2025). Therefore, their findings suggest music may impact taste attributes independently from liking, as sound effects can result in sensory attributes deviating more from the ideal level, yet liking is impacted positively (Swahn et al., 2025). However, it is notable to mention that a significant change in isolated sensory attributes, such as sweetness, in a direction away from ideal may not always result in lower global liking, as many attributes and their interactions may be important for a consumer's overall experience (Moskowitz, 2001). Furthermore, the authors highlight limitations, including not measuring the emotions related to the soundtracks, meaning there is the possibility that the emotions evoked by the music have driven results rather than purely cross-modal effects. For a better understanding of how emotion may mediate cross-modal effects see Spence et al. (2019).

Previous findings have noted differences in bitterness and sweetness for chocolate-related products, based on emotional music, using standard scales and temporal methods (Kantono et al., 2019; Reinoso-Carvalho et al., 2020a). For this reason, and given that bitterness and sweetness may also be interpreted as having an emotional association (Knöferle & Spence, 2012), we have focused our hypotheses on bitterness and sweetness.

Moreover, auditory stimuli can also modulate sensory perception by sensation transference, which can result in the affective judgement of the audio cue impacting the affective judgement of the food being consumed (Spence et al., 2019). Although changes to liking can be somewhat inconsistent in the literature (Swahn et al., 2025), previous studies investigating the effect of emotional music, have also found higher liking ratings in positive emotional music conditions (Reinoso-Carvalho et al., 2019, 2020a) and it is expected that this will be supported in the current study.

It is notable that chocolate has been chosen as the stimuli for a number of studies investigating audio and sensory perception related to food (Guedes et al., 2023a). Therefore, the abundance of existing findings with which to compare on chocolate, enabled us to minimize uncertainty regarding product-related variability while focusing on the influence of emotional music on sensory perception during testing of specific measurement tools, such as the JAR scale and speeded self-report. Moreover, chocolate can allow for the investigation of changes along the sweet–bitter continuum, with changes to cocoa mass often changing bitterness levels (Carvalho et al., 2015), which means use of dark and milk chocolate can allow for an understanding of whether emotional music can have differential effects on consumer responses depending on the composition of the chocolate. The effect of emotional music on such response to chocolate also require further testing. Additionally, chocolate is generally liked, making it a good choice of product for a large study with members of the public, and it is also a food product that may be considered emotional (Fiegel et al., 2019).

1.2. Just-About-Right (JAR)

JAR scales are used as an approach for capturing information on consumer perception of sensory attribute intensity and how this intensity compares to the consumer's ideal (Moskowitz et al., 2008). Often presented with the anchors "much too little" and "much too much" at opposite ends of the scale with Just-About-Right in the centre, the use of such scales can aid product development by understanding key attributes and their link to acceptance (Popper, 2014).

By using the JAR scale, the current study is also better placed to understand whether consumers would recommend different changes to the chocolate based on the music playing when the food was consumed. After all, marketing endeavours have included manipulating environmental cues in retail environments to understand how such changes affect consumer behaviour, and findings have shown changes based on music (Biswas et al., 2019; Caldwell & Hibbert, 1999), lighting (Biswas et al., 2017) and smell (Ward et al., 2003). For an overview of retail ambiance and effects on consumer behaviour see Spence et al. (2014). The findings of studies of this nature have indicated that manipulating environmental sensory inputs can also aid healthy eating choices, a point that has been raised by other researchers specifically discussing audio inputs (Guedes et al., 2023b; Spence et al., 2019). Therefore, by using JAR, the current study will explore whether consumer feedback on attributes are in line with these findings.

However, with JAR, as the consumer is required to consider how much of an attribute there is, as well as their ideal for that specific product attribute, JAR scales may be more demanding for consumers (Moskowitz, 2001). Therefore, it may be expected that cognitive variations may result in JAR scales being affected by audio to a different degree than rating scales. Yet JAR scales are often used in consumer and sensory science, and understanding how they can be affected by contextual cues is important when designing rigorous consumer studies

1.3. Capturing data grounded in reality

As the food industry strives to capture data from consumer-based studies that hold in the real world, there has been a growing focus on adopting testing environments that mimic real-world settings but still allow for experimental control (Giezenaar & Hort, 2021). This has led to increased interest in the use of technology to help recreate real-world eating environments for use in consumer affective testing (Crofton et al., 2021; Low et al., 2021; Schouteten et al., 2024; Zandstra et al., 2020). With this considered, research environments often have numerous contextual cues. In some cases, this may be the music that happens to be playing in an eating environment, such as a cafe, if carried out in a real eating setting, and virtual contexts may have background audio that is congruent with the real environment (Crofton et al., 2021; Kong et al., 2020; Man et al., 2023). Therefore, there is a need to consider how these auditory cues can affect consumer responses. It is also critical to extend existing research by investigating the effects of such auditory cues on consumer reporting of their perceptions, when measurement tools, important for consumer and sensory science, are adopted, if researchers are to test outside of the traditional CLT or sensory booth more frequently.

1.4. Understanding consumer emotions

Product-elicited emotions, in relation to consumer decision-making, also demand much of the sensory and consumer science research community's efforts (Jaeger et al., 2018; Köster & Mojet, 2015; Spinelli et al., 2019). Different measurement tools have been adopted to capture emotions related to products. For instance, speeded response time tasks are growing in popularity in consumer studies, as researchers seek to capture responses closer to automatic than that of traditional self-reported questionnaires (Haase & Wiedmann, 2020; Mauri et al., 2021; N.R.P. et al., 2023; Till et al., 2011). These can capture consumer associations between key terms, including emotional and sensory terms, and the products under investigation (Cuny et al., 2021; Haase et al., 2018; N.R.P. et al., 2023; Till et al., 2011). The automatic nature of cross-modal effects has been found between auditory stimuli and food names or tastes using a version of the implicit association test (Crisinel & Spence, 2009, 2010).

1.5. The current study

The current study adopted an original investigation by exploring the effects of emotional music on JAR and the related penalty analysis, as well on as automatic associations to chocolate. The latter was collected using a task similar to that which has been adopted in research focusing on sensory aspects of a product (Haase et al., 2018). Moreover, to enhance the practical insight afforded by this study, the results have been presented as within-subjects where data from the same participants for both music conditions have been analysed, which is in line with most of the existing literature. However, when considering a standard one-session consumer study, an issue may also arise with playing different audio during testing of different participants. In this case, between-subjects analysis may be more practically relevant (Carvalho & Spence, 2023). Therefore, to better understand the extent to which emotional music would influence results of sensory and consumer studies, exploratory results have also been presented as between-subjects, with only participants' first music condition included in analysis.

This study explored the effects of emotional music on consumer evaluations of chocolate, including liking, Just-About-Right ratings and speeded responses to emotional, functional and sensory terms from a consumer sample in New Zealand. Previous research of this kind has been conducted in New Zealand with changes found brought about by auditory input (Kantono et al., 2019, 2016). The same emotional audio stimuli, as has been used in existing literature (Reinoso-Carvalho et al., 2020a), was adopted in this study and chocolate was chosen as the food stimuli, as there is existing research with this stimuli (Reinoso-Carvalho et al., 2020b, 2017; Wang et al., 2020). Therefore, the current study allows for the effect of emotional music on consumer responses to JAR and a speeded response task to be easily compared with studies using other measurement tools, such as standard response scales and temporal methods.

Based on the literature reviewed, he following hypotheses were tested:

- H_1: Liking ratings of chocolate will be higher in the positive emotional music condition when compared to ratings captured in the negative emotional music condition.
- H_2: Sweetness (JAR) ratings in the positive condition will be significantly higher than in the negative emotional music condition for both types of chocolate.
- H_3: Bitterness (JAR) ratings in the negative condition will be significantly higher than in the positive emotional music condition for both types of chocolate.
- H_4: Participants will have stronger associations between the chocolate and negative emotional terms when in the negative emotional music condition compared with the positive emotional condition; and stronger associations between the chocolate and positive emotional terms, when in the positive emotional music condition compared with the negative emotional music condition.

2. Material and methods

2.1. Participants

The Food Experience and Sensory Testing lab (Feast) team from Massey University ran the experiment at Fieldays, New Zealand, the Southern Hemisphere's largest agricultural event with ~106,000 visitors in 2024. People attending Massey University's stand were asked if they would like to participate in a short chocolate-tasting session, which would require participants to taste chocolate samples. The study was assessed as low risk following the Massey University Human Ethics Committee process (Ethics Notification Number: 4000029055). All participants were informed about the study procedure and signed an electronic consent form before commencing the study. The event ran for four days, with milk chocolate tested by all participants on the first two days and dark chocolate tested by all participants on the final two days. A total of 678 people signed up to carry out the study. After excluding those who did not wait for a testing booth, did not complete the activity or were seen to be distracted, 573 participants provided data for the study, comprising 300 participants who tasted the milk chocolate samples during the first two days of the event and 273 participants who tasted the dark chocolate, during final two days of the event. Therefore, participants tasted only one type of chocolate.

Fig. 1. Example of the chocolate served for the study.

2.2. Stimuli

Chocolate samples were commercially made (Kapiti Chocolate Factory, Paraparaumu, New Zealand) specifically for the study including a 32% milk chocolate and a 47% dark chocolate sample. Samples were served in silver foil packaging, with assigned three-digit codes printed in black (see Fig. 1). All samples were printed with different three-digit codes; thus, participants were unaware that the same chocolate was being served twice in their session. Audio tracks were the same as those pre-validated and used as positive and negative emotional tracks in a study by Reinoso-Carvalho and colleagues (2020a). In the current study, short excerpts of these tracks were looped and participants listened to the audio through JBL (Los Angeles, CA, United States) 720 BT (32 Ohms) headphones. The audio was approximately 70 dB with the maximum headphone safety set at 80 dB. The music played during the chocolate consumption stage, which participants could not skip through until 15 s had passed.

2.3. Response time task

The response time task was designed similarly to that carried out for practical consumer testing situations (Haase & Wiedmann, 2020; Till et al., 2011). However, thirteen words were selected as stimuli for this task, which covered both emotional and sensory terms. The emotional words were taken from a circumplex-insipred questionnaire of emotions, as existing research suggests that including terms that cover both valence and arousal can be beneficial to understanding relationships between sensory attributes and emotions (Jaeger et al., 2020, 2018). As the task involved quick responses, the aim was to use terms that could be easily understood. The model originally included 12 words pairs; however, to prevent consumer fatigue, only eight word pairs were identified for use, by bench-testing with researchers in the Feast lab, Massey University. The word pairs chosen, were those that spanned both valence and arousal. Furthermore, only one word was chosen from the word pair, that identified as the easiest to respond to during bench-testing. The final emotional terms used were “passive”, “nervous”, “relaxed”, “energetic”, “active”, “unhappy”, “bored”, “happy”. The sensory terms “bitter”, “hard”, “creamy”, “sweet”, and “soft” were also used in this task to determine whether variations in sensory perception, brought about by different music conditions, could be found when consumers answered quickly (Haase & Wiedmann, 2020).

The chosen terms appeared in black on a white background, with text size coded at 5% in Inquisit (Inquisit 6.6.3, Millisecond, USA, 2022). Inquisit Web was used to run the script on iPads (6th Generation, Apple, California, 2018). The “no”, “yes” category labels were constantly displayed at the top of the screen, on the side of the relevant mapped response key (“E” and “I” on the keyboard, which were marked up with “no” and “yes” stickers, respectively). Each word was shown twice randomly, as existing research suggests having at least two presentations of each term (Haase & Wiedmann, 2020). Terms were displayed for a maximum viewing time of 3000 ms, with a 1000 ms fixation between words. Participants were asked to respond based on whether they would associate these words with the sample they had just tasted. The task took approximately two minutes.

2.4. Liking task

Participants were asked, in a random order, how much they liked the chocolate, how much they liked the music, and how much they felt the flavour matched the music (Reinoso-Carvalho et al., 2020a). As Likert scales can suffer from limited response variability (Sung & Wu, 2018), a larger 17-point scale was adopted (scaled -8 to 8 with 0 as neutral) to collect responses. The label anchors “not at all” and “very much” were presented at the scale ends. Participants could respond in their own time by pressing “continue” when they had made their decision.

2.5. JAR scales

Participants were asked to rate their opinion of the chocolates’ bitterness, sweetness, creaminess, and hardness. Although hypotheses were only tied to sweetness and bitterness, the other terms were added so the expected changes would not be so obvious to participants. The questions were presented randomly with a 5-point scale displayed below the question. A JAR 5-points scale was choosen following research suggesting smaller JAR scales me be more effective (López Osornio & Hough, 2010). The scale included the label anchors “too little”, “just-about-right”, and “too much” at points 1, 3, and 5 respectively. Participants could respond in their own time by pressing “continue” when they had made their decision.

2.6. Procedure

The order of soundtrack assignment was counterbalanced across participants based on whether the participant’s number was odd or even. The full experiment was coded in Inquisit Lab (Inquisit 6, Millisecond Software, USA, 2022). Inquisit Web was used to run the script on iPads (6th Generation, Apple, California, 2018) in the online mode with an established internet connection. Attached through a USB-lighting cable to each iPad was a QWERTY keyboard (Genius CT, Dubia, UAE) for use in the RT task. All other tasks were completed using the touchscreen. Following information and consent, participants were seated at one of the four booths built into the exhibition stand, (see Fig. 2) and asked to place the headphones comfortably over their ears. In each booth, a small serving tray with two uniquely coded chocolates of the same type was presented along with a glass of water. Participants were shown a short video to provide the session instructions, which ensured the information given to each participant was consistent and as they were wearing headphones were not distracted by the activities going on around them. This video could not be bypassed.

The session instructions requested that participants place the chocolate in their mouth and let it melt for five seconds before consuming the chocolate. A schematic diagram of the experimental design is presented in Fig. 3. All data were saved locally to the iPad initially and automatically uploaded to the Inquisit server after the participants completed the session. Where a participant was seen to be talking to someone else or distracted during testing, their number and time of session were noted using the Inquisit data tab on the iPad so that their data could be deleted before analysis.

2.6.1. Data analysis

R-studio (with R 3.6.0) (R Core Team, 2023) was used with the *tidyverse* package for data wrangling (Wickham et al., 2019). JASP (JASP Team, 2024) was used for data analysis and XLSTAT (v.2023.1.6, Lumivero, 2023) was used for penalty analysis. The hypotheses were tested using within-subjects analyses, as this accords within the majority of the existing literature. However, between-subjects analysis can allow for a more practical understanding for researchers. For instance, answering the question of whether playing different music during testing sessions may affect the outcomes of consumer and sensory studies (Reinoso-Carvalho et al., 2020b) and improve external validity (Carvalho & Spence, 2023). Therefore, it was added for exploratory purposes. For between-subjects analysis, data from the first music condition only was considered and data from participants receiving the negative emotional music were compared with participants hearing positive emotional music during chocolate consumption (see Fig. 4).

To test the effect of music condition on chocolate ratings, paired t-tests were run for within-subjects analyses and independent t-tests for the between-subjects analyses.

For the RTT, association responses with latencies of less than 300 ms and those exceeding 3000 ms were excluded from analysis (Greenwald et al., 1998) resulting in 4% of trials removed from RT analyses for dark chocolate and 3.3% of RT trials removed for the milk chocolate condition.

Citation frequencies were determined by the association direction value. This was assigned based on whether participants responded “yes”, (value = 1) or no (value = 0). Associations were considered “yes” where all valid participant responses were “yes”, while a “no”, “yes” was termed “no”. Where analysis was carried out with data from the same participants, the McNemar’s test was adopted, and where it was carried out with data from different groups of participants, a chi-squared test of independence was adopted.

For JAR data, JAR was considered a scale with 'too little' being of negative sign, ‘JAR’ zero, and 'too much' a positive sign (scale = -2 to 2, as 5-point JAR adopted) (Zandstra et al., 2020). A penalty analysis was conducted, which involved the use of the consumer liking data as well as their JAR rating of sensory attributes. For instance, whether the consumers find sweetness too little, too much or just-about-right. These data were then grouped based on their rating of each attribute. The average overall liking score was then calculated for each group. If the too sweet or not sweet enough groups gave lower liking scores than the just-about-right group, the difference was noted as a penalty to liking (now only referred to as penalty). Attributes were considered for penalty analysis only if 20% or more of consumers rated them as either too little or too much (Xiong & Meullenet, 2006). Analysis of penalties included directional aspects, that is whether the attribute was found to be “too little” or “too much” and how this affected liking. It was also considered in terms of overall penalties based on the attribute being not-JAR compared to when it was JAR.

Bonferroni correction was used to adjust the alpha value (.05) to control for family-wise error where multiple tests were carried out during conjunction testing (Rubin, 2021), that is, where any individual test could be used to reject a null hypothesis. For instance, in the analysis relating to H_4, there were eight emotional terms that could be

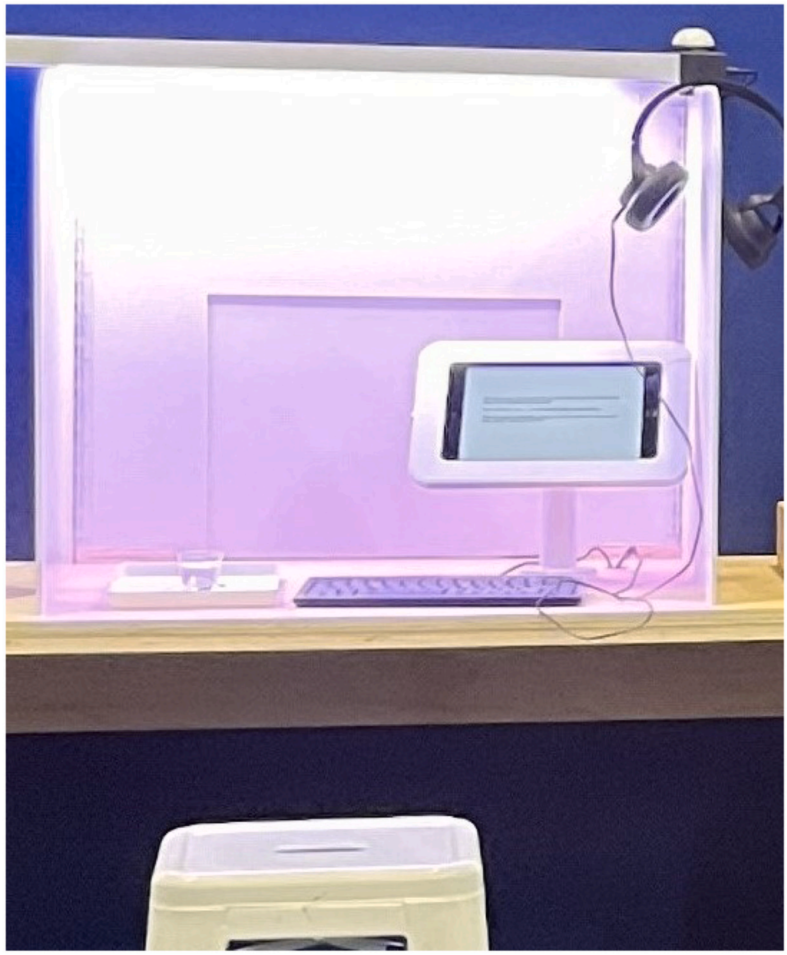

Fig. 2. One of four participant booths made of white board and lit with white lighting from above.

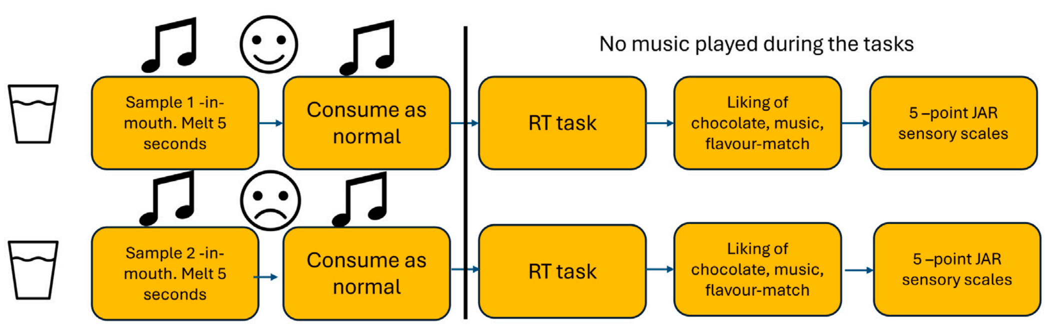

Fig. 3. Experiment procedure showing the order in which participants carried out each of the tasks. Before the first sample was tested, participants were instructed to have a sip of water. Between samples a 15-second minimum palate cleanse period was imposed with participants instructed to drink water. The order of positive and negative audio clips was counterbalanced across participants using subject number. This music was played during sample consumption until the participant responded to indicate they had swallowed the full sample. Demographic information was collected at the end of all experimental blocks. Note: water icon from Flaticon.com and all others from Microsoft Powerpoint.

used to support the theory that emotional associations to the chocolate when the emotional audio cues changed. Therefore, in this example the alpha was adjusted (.05/8 =.006). Where analyses were exploratory, no corrections for familywise error were carried out. Where data were not found to meet assumptions of normality, non-parametric equivalent tests were run this was check at the level of each individual analysis. Thus, where Wilcoxon signed-rank tests were carried out for within-subjects analysis, or a Mann–Whitney U tests for between-subjects analysis the data did not meet assumptions of normality.

3. Results

3.1. Liking ratings by music condition

3.1.1. Within-subjects - Liking

A Wilcoxon signed-rank test revealed the negative emotional music was rated significantly lower for liking than the positive emotional music for participants tasting milk and dark chocolate (Milk chocolate $z = -11.38$, $p < .001$, $r_b = 0.81$; Dark chocolate $z = -11.28$, $p < .001$, $r_b = 0.82$). Paired t-tests found the positive music matched the chocolate

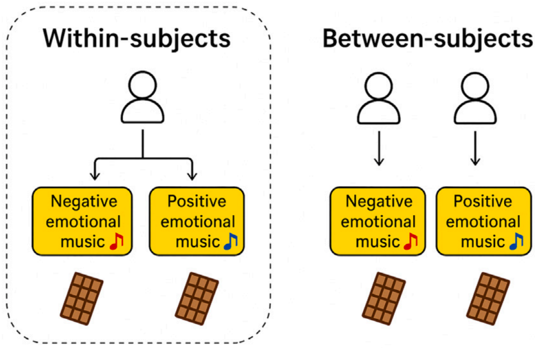

Fig. 4. Participants tasted the same chocolate while listening to two different types of music. The order of the music conditions was counterbalanced so that some participants heard one type first, and others heard the opposite type first. For the within-subjects analysis, each participant's responses across the two music conditions were compared (shown with the dashed line). To also explore the effect of emotional music without relying on direct within-person comparisons, we conducted a between-subjects exploratory analysis. In this case, only the first tasting from each participant was included. This meant comparing responses from the group of participants who first heard negative music with the other group who first heard positive music.

significantly better than the negative music did (Milk chocolate $t(299) = 16.43$, $p < .001$, $d = 0.95$; Dark chocolate $t(272) = 10.12$, $p < .001$, $d = 0.6$). A Wilcoxon signed-rank test run on liking ratings of milk chocolate found no significant effect of music condition ($z = 0.73$, $p = .461$) with liking ratings not significantly different between the positive (Mean = 2.48, SD = 3.44) and negative emotional music conditions (Mean = 2.35, SD = 3.42). This was not the case for the dark chocolate, where liking ratings in the negative emotional music condition were significantly lower (Mean = 1.38, SD = 3.74) than in the positive emotional music condition (Mean = 1.87, SD = 3.67), ($z = -2.40$, $p = .016$, $r_b = 0.19$).

3.1.2. Between-subjects - Liking

Results revealed there were no significant differences for milk chocolate liking rating for participants in the negative emotional music (Mean = 3.06, SD = 3.08) and the positive emotional music condition (Mean = 2.24, SD = 3.68), ($z = 1.89$, $p = .058$). A Mann–Whitney U test revealed no difference for dark chocolate liking ratings for participants in the negative emotional music condition (Mean = 1.65, SD = 3.65) and the positive emotional music condition (Mean = 1.46, SD = 3.78), ($z = 0.40$, $p = .686$). Participants liked the negative emotional music significantly less and rated it as a worse match to the chocolate than the positive emotional music for both chocolate types, (all $ps < .001$).

3.2. Citation frequency in the response time task - within-subjects

Citation frequency of terms in the RTT for milk chocolate, showed significant differences following Bonferroni correction, for the emotional terms happy, nervous, relaxed and unhappy. Differences were also found for the sensory terms bitter, creamy, hard, soft, and sweet. However, low citation numbers for bitter and nervous mean they should be interpreted with caution (see Table 1).

Citation frequencies of RTT terms for dark chocolate, showed significant differences, following Bonferroni correction, for the emotional terms happy, nervous, passive, relaxed and unhappy. Differences were also found for the sensory terms bitter, creamy, soft, and sweet. However, low citation numbers for unhappy and nervous mean they should be interpreted with caution (see Table 2).

3.3. Citation frequency in the response time task - between-subjects

Chi-Squared tests run on the milk chocolate data, found significant results when considering frequency of citations by music condition as a between-subjects factor, for the emotional terms active ($p = .012$), nervous ($p = .002$), happy ($p = .027$), relaxed ($p = .004$) and unhappy ($p = .002$). Active, nervous and unhappy were cited more in the negative music condition than the positive music condition. Happy and relaxed were cited more in the positive music condition than the negative music condition. The sensory term hard was also cited significantly more in the negative music condition than with the positive music ($p = .035$). For the dark chocolate, only emotional terms nervous ($p = .002$) and relaxed ($p = .001$) revealed significant differences. Nervous was cited more in the negative music condition than the positive music condition, and relaxed was cited more in the positive music condition than the negative music condition.

3.4. Sensory perception

3.4.1. Within-subjects - sensory responses

Paired t-tests found sweetness to be the only sensory attribute that differed in ratings based on music condition and for the milk chocolate only. The chocolate, when consumed with positive emotional music, was rated higher for sweetness (Mean = 0.33, SD = 0.63), than with negative emotional music (Mean = 0.26, SD = 0.68), ($t(299) = 2.00$, $p = .046$, $d = 0.12$) (see Table 3 for details).

3.4.2. Between-subjects - Sensory

Mann–Whitney U tests revealed no significant differences in any of the sensory attribute JAR ratings by music condition for the milk or the dark chocolate (all $ps > .059$).

3.4.3. Penalty analysis - Within-subjects

For the milk chocolate, penalties occurred for "too little" bitterness, "too much" hardness and "too much" sweetness in both music conditions. However, as shown in Table 4, "too little" creaminess resulted in a significant penalty in the positive music condition only (Mean drop = 2.65, $p < .001$). However, the penalties were numerically similar across the music conditions. Furthermore, when considering attributes at the ideal level (JAR) versus when they are out of the ideal level (non-JAR) (e.g. deviations in either direction), all attributes significantly affected liking in both the negative and positive emotional music conditions (all $ps < .05$).

For the dark chocolate, as can be seen by Table 5, there were penalties in liking for "too little" creaminess, "too much" hardness and "too much" sweetness in both music conditions. However, "too little" sweetness led to a significant mean drop in liking in the negative music condition alone (mean drop = 3.52, $p < .001$), although the mean drop for this attribute was numerically similar across music conditions. Furthermore, when considering JAR versus non-JAR effects on liking (e.g. deviations in either direction) all attributes were significant for both the negative and positive emotional music conditions (all $ps < .05$).

3.4.4. Between-subjects penalty analysis

As can be seen by Table 6, liking of milk chocolate was dependent on a similar number of attributes in both music conditions; however, the negative music condition showed penalties when the chocolate was considered to be too hard, while the positive music condition showed a mean drop in liking where the product was found to be too little in creaminess. When considering attributes at the ideal level (JAR) versus when they are out of the ideal level (non-JAR) (e.g. deviations in either direction), there were significant differences for all attributes in the negative music condition ($ps < .05$), whereas, hardness did not result in a significant penalty to liking for those listening to positive emotional music ($p = .095$).

Table 1
Citation frequency for each term in the negative and positive emotional music conditions respectively for milk chocolate. Different letters on the same row indicate significant differences using McNemar's test. Rows in bold relate to the term for which significance held after familywise corrections applied.

Attributes	**negative**	**positive**	**p-values**
Active	0.383 (a)	0.333 (a)	0.101
Bitter	**0.080 (b)**	**0.040 (a)**	**.045**
Bored	0.080 (a)	0.067 (a)	0.556
Creamy	**0.793 (a)**	**0.853 (b)**	**.028**
Energetic	0.377 (a)	0.347 (a)	0.349
Happy	**0.677 (a)**	**0.850 (b)**	**<.0001**
Hard	**0.480 (b)**	**0.407 (a)**	**.039**
Nervous	**0.123 (b)**	**0.040 (a)**	**.000**
Passive	0.283 (a)	0.323 (a)	.219
Relaxed	**0.503 (a)**	**0.810 (b)**	**<.0001**
Soft	**0.420 (a)**	**0.490 (b)**	**.036**
Sweet	**0.800 (a)**	**0.897 (b)**	**.000**
Unhappy	**0.087 (b)**	**0.007 (a)**	**<.0001**

Table 2
Citation frequency for each term in the negative and positive emotional music conditions respectively for dark chocolate. Different letters on the same row indicate significant differences using McNemar's test. Rows in bold relate to the term for which significance held after familywise corrections applied.

Attributes	**negative**	**positive**	**p-values**
Active	0.403 (a)	0.363 (a)	.278
Bitter	**0.341 (b)**	**0.234 (a)**	**.001**
Bored	0.088 (a)	0.077 (a)	0.710
Creamy	**0.601 (a)**	**0.703 (b)**	**.004**
Energetic	0.425 (b)	0.333 (a)	.011
Happy	**0.586 (a)**	**0.821 (b)**	**<.0001**
Hard	0.436 (a)	0.407 (a)	.480
Nervous	**0.176 (b)**	**0.029 (a)**	**<.0001**
Passive	**0.249 (a)**	**0.341 (b)**	**.006**
Relaxed	**0.381 (a)**	**0.751 (b)**	**<.0001**
Soft	**0.282 (a**	**0.403 (b)**	**.001**
Sweet	**0.619 (a)**	**0.718 (b)**	**.003**
Unhappy	**0.099 (b)**	**0.033 (a)**	**.002**

Table 3
JAR results (mean and standard deviations) for each attribute by chocolate type and music condition. Different letters in the mean column of the same row denote statistically significant differences between music conditions.

Milk				
	Negative		Positive	
Attributes	Mean	SD	Mean	SD
Bitterness	−0.28 a	0.67	−0.34 a	0.63
Creaminess	−0.08 a	0.52	−0.14 a	0.59
Hardness	0.27 a	0.64	0.21 a	0.6
Sweetness	0.26 a	0.68	0.33 b	0.63
Dark				
	Negative		Positive	
	Mean	SD	Mean	SD
Bitterness	−0.02 a	0.79	−0.07 a	0.66
Creaminess	−0.36 a	0.65	−0.29 a	0.63
Hardness	0.33 a	0.64	0.31 a	0.63
Sweetness	−0.01 a	0.76	0.06 a	0.7

Table 4
Penalty analysis results for all sensory attributes of the milk chocolate by music condition. Values represent penalties measured on 17-point scale. Significant (p <.05) penalties are in bold.

Music condition	Bitterness		Sweetness		Creaminess		Hardness	
	Too Little	Too Much	Too Little	Too Much	Too Little	Too Much	Too Little	Too Much
Positive music	**1.51**	1.60	2.27	**2.66**	**2.65**	1.60	1.33	**1.25**
Negative music	**2.07**	4.60	3.53	**2.04**	2.45	1.42	1.42	**1.00**

Table 5
Penalty analysis results for all sensory attributes of the dark chocolate by music condition. Values represent penalties measured on 17-point scale. Significant (p <.05) penalties are in bold.

Music condition	Bitterness		Sweetness		Creaminess		Hardness	
	Too Little	Too Much	Too Little	Too Much	Too Little	Too Much	Too Little	Too Much
Positive music	1.22	4.00	3.21	**1.55**	**2.19**	−0.01	1.77	**1.50**
Negative music	1.92	2.99	**3.52**	**1.5**	**2.39**	0.68	0.85	**2.10**

Table 6
Penalty analysis results for all sensory attributes of the milk chocolate for first music condition only looked at as between-subjects. Values represent penalties with liking measured on 17-point scale. Significant (p <.05) penalties are in bold.

Music condition	Bitterness		Sweetness		Creaminess		Hardness	
	Too Little	Too Much	Too Little	Too Much	Too Little	Too Much	Too Little	Too Much
Positive music	**1.46**	0.13	2.06	**3.05**	**2.45**	1.91	1.71	0.84
Negative music	**2.16**	1.912	3.02	**1.67**	2.59	−0.09	1.14	**1.17**

Table 7
Penalty analysis results for all sensory attributes of the dark chocolate for first music condition only looked at as between-subjects. Values represent penalties with liking measured on 17-point scale. Significant (p <.05) penalties are in bold.

Music condition	Bitterness		Sweetness		Creaminess		Hardness	
	Too Little	Too Much	Too Little	Too Much	Too Little	Too Much	Too Little	Too Much
Positive music	1.59	4.02	3.26	1.53	**2.51**	−1.00	−0.90	1.30
Negative music	**2.25**	3.61	4.02	**1.70**	**2.39**	1.16	1.21	**2.94**

As can be seen by Table 7, liking of the dark chocolate was dependent on many more attributes in the negative music conditions when statistically meaningful penalties were considered. In general, penalties were larger in the negative music condition. However, when considering JAR versus non-JAR effects on liking, there were significant effects for all attributes in the negative music condition (ps <.05), whereas, hardness was not a significant penalty when listening to positive emotional music (p=.094).

4. Discussion

4.1. Effects of music

This study set out to extend the current literature, by examining effects of emotional music on sensory perception using measurement methods of interest for consumer product testing, including JAR scales and an emotion/sensory RTT, the likes of which have been used with consumers (Haase et al., 2018; Till et al., 2011). Hypothesis one stated that, "Liking ratings of chocolate will be higher in the positive emotional music condition when compared to ratings captured in the negative emotional music condition". This was partially supported as there were differences in liking ratings, based on music condition for the dark chocolate, with the chocolate eaten in the positive emotional music condition receiving higher liking ratings than the chocolate consumed in the negative emotional music condition.

However, there were no differences in liking based on music condition, for the milk chocolate. Notably, the milk chocolate differed in sensory ratings, based on music condition. Indeed, H_2 which stated that "Sweetness (JAR) ratings in the positive condition will be significantly higher than in the negative condition for both types of chocolate" was not supported, as there was only a significant difference for sweetness for milk chocolate, with the positive music condition eliciting higher sweetness ratings, which moved further from JAR (zero on the scale) than in the negative music condition. Therefore, it may be that the changes in sensory perception of sweetness brought about by the music were not entirely beneficial for the milk chocolate and mitigated any positive changes in liking brought about by the music, which may occur through sensation transference, whereby individuals project their emotional reaction to the audio cue onto their perception of the food (Spence et al., 2019).

Findings of research using JAR scales during the consumption of chocolate ganache in different sound conditions, including bitter and sweet, suggest that the effects of audio on sensory perception during consumption, are independent of liking (Swahn et al., 2025). The current study found liking and sensory aspects to be affected differently. That is, liking was significantly different for dark chocolate but there was no significant difference for any sensory attributes for this product. While for the milk chocolate in the current study, sweetness moved further from ideal in the positive emotional music condition, and unlike in the study by Swahn et al. (2025), we did not find increased liking in this condition. Arguably, we may have expected that a change in a direction away from ideal would result in a lower liking rating, but this did not occur. However, given that food products have several different relevant sensory attributes, and these attributes may be differentially affected by music, there is a challenge in separating sensory changes from changes in liking ratings when liking and sensory ratings are looked at separately. Furthermore, findings of JAR tests are not always straightforward; for instance, a modified product changed to meet ideal levels on all attributes suggested by consumers, is not always the product considered the best in terms of acceptance (Moskowitz et al., 2008). Meaning consumer-advised sensory changes do not always lead to optimal liking. However, penalty analysis does allow for the sensory drivers of liking to be explored; therefore, by running separate penalty analyses in each music condition, there is scope to investigate whether the emotional tone of the music would result in differences to the attributes noted by consumers as being important for liking, based on music.

Penalty analysis revealed limited differences, as overall penalties were found for all attributes during both music conditions. There were some differences with the directional results, that is, when looking at the statistically meaningful changes that are highlighted for product developers depending on the music condition; however, when looking at the magnitude of the penalties, they were similar across music conditions. Therefore, depending on whether a product developer was focusing on a numeric cut-off or a significant difference in penalties would affect whether the music played during testing would have an impact on product development or not (Moskowitz et al., 2008).

Between-subjects analysis revealed bigger differences in both magnitude and statistically meaningful differences based on music condition for the dark chocolate. For instance, it was found that statistically significant penalties were present for "too little" bitterness, "too much" sweetness, and "too much" hardness in the negative, but not the positive emotional music condition. This suggests that consumers listening to the negative music highlighted more attributes important for liking than consumers in the positive music condition, which may be down to the emotional valence aspects of the music transferring to consumer responses, in line with the idea of sensation transference (Spence et al., 2019) to a greater degree when consumers have no other music condition to compare with. The outcome may also be due to a change in the attention given to an attribute for some consumers, with attention heightened to attributes congruent with the music playing (Wang et al., 2017). For instance, if consumers are giving more attention to the bitterness attribute and some still feel the chocolate is not bitter enough, it may result in a detrimental effect on the liking score. There is also the possibility that the difference between the individuals in each condition impacted these results.

From a health point of view, the results of the between-subjects analysis suggest that some consumers may be more accepting of dark chocolate with lower sweetness levels with negative emotional music playing, but whether this happens at a behavioural level would require further investigation, as the current study is only showing this effect with self-reported measures. However, when statistically meaningful penalties were considered, these being the penalties between JAR and non-JAR attributes regardless of attribute direction, then for both chocolate types the between-subjects results highlighted differences with only the hardness attribute, in that hardness only penalized liking when it was not JAR in the negative music condition. Previous research with emotional music found chocolate was rated as having a softer texture when consumed while listening to positive emotional music and as having a harder texture when consumed with negative emotional music (Reinoso-Carvalho et al., 2020b). We did not however, find these affects in the ratings of hardness or creaminess when the JAR results were looked at on their own; the differences were only found with penalty analysis, suggesting that the change is in relation to the drivers of liking for the attribute hardness, which increases in importance with the negative emotional music. The results of the current study support the idea that carrying out consumer tests typical in product development, may result in different results, especially with textural attributes, if different music is used across sessions. Differences in bitterness JAR ratings were not found for either chocolate and H_3 was not supported. Previous research has found changes to liking ratings, sweetness and bitterness for milk and dark chocolate (bitterness ratings of dark chocolate were not significantly different for the participants in Japan but were found for Colombian participants) based on emotional music (Reinoso-Carvalho et al., 2020a). A further study by Reinoso-Carvalho et al. (2020b) using emotional music and chocolate, carried out with a large sample of participants in South Korea, found changes to sweetness and softness based on emotional music, with no significant differences in bitterness ratings. There were no significant differences for sweetness JAR ratings of dark chocolate based on music condition in the current study, but the penalty analysis did show that changes to the importance of this attribute may occur based on the emotional tone of the music as this had a significant impact on liking ratings of dark chocolate in the negative music condition only. Cultural variations may influence the difference in these results. However, Kantono and colleagues found disliked music evoked bitterness while positive music evoked sweetness for *gelato* when using the Temporal Dominance of Sensation method (TDS) to collect responses from a sample of consumers in New Zealand (Kantono et al., 2019). Therefore, alternatively, differences in results between this study and that of Kantono et al. (2019) may be driven by differences in the methods adopted. For instance, the food stimuli used differed between studies as did the measurement tools. With the current study using a static response method, which may require different cognitive demands to a temporal dominance measurement tool. Furthermore, JAR may be less sensitive to change than a measure that requires consumers to consider dynamic changes to dominant attributes during tasting; a dominant attribute is not necessarily the most intense but the attribute demanding the most attention (Pineau et al., 2009).

Interestingly, the speeded response results differed when comparing within-subjects and between-subjects analysis. H_4 was supported as, for both chocolate types, negative emotions were cited more frequently in the negative emotional music condition and positive emotions were cited more frequently in the positive emotional music condition. This was also the case for between-subjects analysis. Existing research suggests speeded responses may be closer to automatic (Ranganath et al., 2008). As consumers have less time to respond, they may be expected to be more susceptible to change based on the multi-sensory experience. However, for the sensory association terms in this task, differences were predominantly found when the same people provided data for both music conditions. Therefore, the sensory differences appear to be driven mainly by the comparative aspect of the study. Indeed, existing literature highlights that some cross-modal effects can only be seen within-subjects (Carvalho & Spence, 2023) and this may be the case for the effects of emotional music.

However, the differences in penalty analysis were mainly shown between-subjects, suggesting the comparative aspect (within-subjects) allows for more consistent results. This can have practical implications; for instance, if a researcher does not keep background music consistent across replicates, samples, or sessions when running one-session sensory studies. As the dark and milk chocolate samples were differentially impacted, the findings also point to product specific results, which is in line with previous findings (Reinoso-Carvalho et al., 2020a; Swahn et al., 2025).

Taken together, the findings suggest the measurement tool adopted can also impact findings of multi-sensory consumer and sensory studies. The results of this study support an effect of emotional music on consumer responses to chocolate and suggest that for sensory and consumer researchers who aim to capture data that transfer to the real-world, it may be worthwhile to test certain products in contexts with auditory contextual cues as well as sensory booths, to test product stability. This may be especially important for products that are expected to be consumed in environments with loud background noise, such as nightclubs.

4.2. Limitations and future research

This study was carried out at a large public event in New Zealand, which meant the study benefited from a diverse population sample. However, as it was carried out at a busy public event there were limitations on the time consumers had available to be involved in the study. There were also external influences that we could not fully control for; for instance, there is the potential that some participants may have been distracted during the test. However, the position of our portable booths meant the participants had their backs to any event activity. Also, the study did not allow for individual differences to be captured, such as food related behaviours, and sensory sensitivity. Understanding such differences could help to better comprehend the drivers of the outcomes of multi-sensory studies (Spence, 2022). Individual liking of the musical pieces was not captured and there is the potential that some consumers liked the negative emotional music or disliked the positive emotional music, which may have led to differences at an individual level (Garrido & Schubert, 2011; Juslin et al., 2022). Including such measures may have allowed for a better insight into the overall findings. Future research should also address the mechanisms driving the changes in the associations between perception of an attribute and liking.

Furthermore, the results of this study offer information on consumer responses based on emotional music; however, the music stimuli will also differ on musical dimensions, and it can be difficult to disentangle these from emotion (Guedes et al., 2024). There is also the possibility that we could have gained clearer insight by selecting a dark chocolate with a higher cocoa content. Moreover, our study used headphones and music stimuli that may be regarded as extreme. Therefore, there is a need to check the effects of less extreme emotional music delivered as background sound on the measurement tools used in this study. Finally, future research should go further and check how emotional music influences the wanting and consumption of foods in consumer sensory environments to see whether consumer behaviour towards newly developed products changes based on audio cues.

5. Conclusions

This study extends the existing literature investigating the effect of emotional music on sensory perception by including the JAR scale and an RTT task. The results emphasize the importance of considering the multi-sensory testing environment. If rapid responses are to be captured, then they are likely to be highly susceptible to effects of audio input. Furthermore, this study shows that emotional music can impact the sensory attributes and the attributes highlighted as important for liking depending on the study design. Therefore, decisions on the inclusion of music in consumer testing, such as when mimicking real-world environments with digital immersive technology, should be considered fully to ensure results are useful in an applicative sense by ensuring decisions on audio are representative of the consumption scenario.

CRediT authorship contribution statement

Jennifer Wagner: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Simone Poggesi:** Writing – review & editing, Methodology, Data curation, Conceptualization. **Robyn Maggs:** Methodology, Data curation. **Joanne Hort:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Conceptualization.

Ethics approval

The study was assessed as low risk following the Massey University Human Ethics Committee process (Ethics Notification Number: 4000029055). All participants were informed about the study procedure and signed an electronic consent form before commencing the study.

Funding statement

This research was supported by The Fonterra Research and Development Centre by funding JW's time.

Declaration of competing interest

None.

Acknowledgements

Thanks to Elise Waddell and Jenna Fryer who helped with data collection, to Massey University for inviting Feast to attend Fieldays and to the Feast team who helped with the planning and execution of the study. The authors would also like to express thanks to all participants who contributed their time to take part in this study.

Data availability

Data will be made available on request.

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