Received: 27 January 2023 | Revised: 13 March 2023 | Accepted: 17 May 2023

DOI: 10.1111/joss.12855

ORIGINAL ARTICLE

Journal of Sensory Studies | WILEY

Identifying temporal drivers of product acceptance and rejection across sips during whole product consumption

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Funding information
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Abstract

Measuring emotional response gives insights into consumer product experiences beyond liking. However, existing research rarely considers that emotional and hedonic responses can change during consumption of a whole portion. This research considered how well a combined multiple-sip temporal check-all-that-apply approach captured temporal drivers of product acceptance and rejection. Consumers ($n = 104$) profiled temporal sensory, liking and emotional responses to three milkshakes. Associations in temporal sensory, liking and emotional response citation pattern across multiple sips were investigated using generalized linear models, analysis of deviance and Pearson's chi-square test. Differences in the temporal dynamics of sensory, liking and emotional responses and associations between temporal sensory and affective responses were identified highlighting liking and emotional experience were related to the evolution of sensory attributes over time. Notably, sensory associations with emotional responses, including "bored," "relaxed," and "satisfied," were better at identifying temporal drivers of acceptance/rejection more than associations to level of liking.

Practical Applications

The research demonstrated that a combined multiple-sip temporal check-all-that-apply (TCATA) approach, representing whole product consumption, is an effective approach to gain deeper insights into the sensory drivers of consumer affective response. However, the applicability of analyzing within-sip variations in perception, and potential to use check all that apply by sip as opposed to TCATA needs to be considered on a product category basis.

1 | INTRODUCTION

Descriptive sensory data are often combined with consumer hedonic responses to understand consumer experience of foods (Kemp et al., 2009). However, competition in the food industry is increasing demand for better insights into consumer product experience beyond hedonic measurements (Ng & Hort, 2015). Measuring emotional response alongside sensory profiling of products has become more popular in recent sensory and consumer research (Peltier et al., 2019; Spinelli & Monteleone, 2018). Some perceptions, such as bitterness, have been shown to evoke the disgust emotion (Schienle et al., 2020) and serve as a possible driver for product dislike/rejection. Measuring emotional response has been shown to provide better product discrimination and insights into product engagement in comparison to hedonic responses (Ng et al., 2013; Nijman et al., 2019). Furthermore, emotions are known to impact hedonic responses (Parker et al., 2006), amount of food consumed, food acceptance and rejection (Macht, 2008). Therefore, measuring hedonic and emotional responses alongside descriptive sensory data can deliver a more complete overview of consumer food experiences.

Conventional descriptive sensory techniques are often designed to capture a single response related to sensory attributes during product evaluation (Kemp et al., 2009). Primarily, emotion and liking responses have been captured using static methods (Ng et al., 2013). Such static techniques are reported to provide an averaged overview of the whole consumption experience (Cliff & Heymann, 1993; Dijksterhuis & Piggott, 2000) or sensory perception at a specific time point as dictated by tasting protocols (Hort et al., 2017). Since early insights into the time dependent nature of sensory perception (Holway & Hurvich, 1937), different techniques have been developed to capture the dynamic sensory profiles of products (Castura et al., 2016; Cliff & Heymann, 1993; Jack et al., 1994; Pineau et al., 2009; Visalli et al., 2020). Adapting temporal sensory techniques to understand consumer affective response in terms of temporal hedonic and emotional reactions presents as an obvious development opportunity. These adaptations have enabled researchers to identify temporal drivers of product acceptance and rejection, for example, Lorido et al. (2019) applied temporal dominance of sensory (TDS) and emotions (TDE) techniques alongside overall liking of ham.

Extending temporal sensory and emotional response measurements using a temporal check-all-that-apply (TCATA) approach (Castura et al., 2016) could capture simultaneous evolution of sensory perceptions and emotions. There are two TCATA variants. Originally, a list of product specific attributes was presented to panelists instructed to continuously select and de-select attributes as they evolved at any time point throughout the evaluation. Later, TCATA fading, a variant of the original TCATA was presented by Ares et al. (2016), where the selected attributes fade to "unselected" over a predefined period of time. Panelists are instructed to reselect the attributes if they are still applicable during the evaluation time. The TCATA fading variant, in comparison to original TCATA, has improved product discrimination and accuracy of dynamic sensory profiles of products with naïve consumers (Ares et al., 2016).

Temporal methods are usually used to evaluate a single bite or sip of a product (Lorido et al., 2019; Ng et al., 2012). Silva et al. (2018, 2019) extended product evaluation over four plus sips to capture dynamics of sensory perception, emotional response and liking using TDS, TDE, and temporal liking, respectively. Weerawarna N. R. P. et al. (2021) extended the TCATA approach over eight sips to represent consumption of a typical serving of milkshake to capture the dynamics of sensory attribute evolution throughout the whole product consumption experience. Thomas et al. (2016) adapted an approach using TDS and liking scale to evaluate full portion of an oral nutritional supplement. To date no research investigating temporal drivers of acceptance during whole product consumption using TCATA methodology has been published. However, further adaptation of a multiple-sip TCATA approach including measures of liking and emotional response alongside sensory measures provides that opportunity.

Nevertheless, TCATA methodology is still evolving and gaps remain in how best to analyze or model TCATA data. TCATA captures the simultaneous evolution of attributes during product evaluation in terms of citation frequencies given by panelists (Castura et al., 2016). The citation frequencies of each attribute are then calculated as proportion data during data manipulation (Castura et al., 2016; Pineau et al., 2009). TCATA records data at a high frequency of 0.01 s (Castura et al., 2016) and produces autocorrelated data (Box et al., 2005) on adjacent time slices. In the TCATA fading method (Ares et al., 2016), all pairs of time slices closer together than the fading time are essentially correlated. Data being independent (i.e., not correlated), normally distributed and having a constant variance are fundamental assumptions of standard linear models with analysis of variance (ANOVA) (Box et al., 2005). Consequently, standard linear models and ANOVA cannot be applied to analyze correlated data from TCATA.

There is, however, an alternative approach to analyze correlated temporal data. Generalized linear models (GLM) and analysis of deviance are standard approaches recommended to analyze proportions or counts based data (Agresti, 2018b). In statistical analysis, a likelihood function is used to explain the goodness of fit, that is, the difference between observed and the expected values of a fitted model to a respective data set. For computational convenience, likelihood is often calculated as log-likelihood, which represents the additive of log-likelihood of individual observations (Box et al., 2005). Deviance is denoted by two times the log-likelihood (Agresti, 2018b). As a fitted model gets closer to the observed data, the likelihood tends toward one, and the deviance therefore reaches to zero. The advantage of an analysis of deviance approach is that it is based on the fitted values for the models being compared and does not rely on the ability to correctly estimate standard errors for estimates as would be needed in standard linear models and ANOVA (Agresti, 2018b). Therefore, analysis of deviance avoids problems caused by the lack of independence amongst observations or having nonconstant variances, both of which compromise hypothesis testing for standard linear models. analysis of deviance uses omnibus tests for each main effect and interaction by way of Chi-square distribution, with degrees of freedom determined by each main effect and interaction (Montgomery et al., 2012).

The aim of this research was to adopt this alternative statistical approach and evaluate the effectiveness of a combined multiple-sip TCATA approach (sensory attributes/emotional response/level of liking) in identifying temporal drivers of product acceptance and rejection during whole product consumption. More specifically, temporal drivers were identified by investigating the relationship between citation patterns in temporal sensory responses and citation patterns in both temporal liking and emotional responses across multiple sips.

2 | MATERIALS AND METHODS

Massey University Human Ethics Committee approval (application ID: SOA 19/50 and 4000021034) was obtained for this research. All product preparation and sample evaluations were carried out in the Feast laboratory, at Massey University, Palmerston North campus,

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New Zealand. All participants were offered an inconvenience allowance (NZ$25 voucher) per session to participate and gave written informed consent.

2.1 | Products

Three vanilla milkshakes (X, Y, and Z) were manufactured using whole milk powder, skim milk powder, thickener blend (micro crystalline cellulose, carboxy methyl cellulose, and carrageenan) (Fonterra, New Zealand); A1 sucrose, yellow coloring (Davis Food Ingredients, New Zealand); stevia (Stevita, New Zealand); vanilla flavor, vanilla cream flavor (Invita NZ Ltd, New Zealand); and filtered water (chlorine, taste, and odor removal carbon cartridge filter at 1 μm) using a Thermomix (TM5, Vorwerk Electrowerke GmbH & Co. KG, Germany) in the Product Development Laboratory at Massey University Palmerston North campus as detailed in Weerawarna N. R. P. et al. (2021). Stevia was added in product Z to yield equivalent sweetness to low sucrose level in product Y. The milkshakes were developed to provide a wide range of sensory experiences. Final product composition is shown in Table 1. Amount of vanilla flavor and color were kept the constant across all the tree formulas. During the preparation, milkshakes were heated up to 90 ± 1°C and held for 2 min at a mixing speed of 2.5 in the Thermomix. The heat treated mixture was immediately transferred into a stainless-steel beaker and cooled to 60 ± 1°C in an ice water bath followed by the addition of the vanilla flavors. The final vanilla milkshake was packaged in PET containers and stored at refrigerated conditions (5 ± 1°C). Products were used within 2 days of the preparation date.

2.2 | Sensory lexicon development

A sensory lexicon (Table 2), previously developed by a trained panel, was used to evaluate the sensory characteristics across the milkshakes as detailed in Weerawarna N. R. P. et al. (2021).

2.3 | Emotion lexicon development

To date, no dairy beverage specific emotion lexicons are available in the literature and consequently group discussions were conducted to generate a consumer-defined emotion lexicon relevant to the milkshakes.

Discussion group participants were recruited from Massey University Palmerston North campus and Palmerston North city. Then, 24 consumers (16 females and 8 males) aged 18–65 years, who met the following criteria: native speakers of, or competent in the English language, consumed milkshakes at least once a week and had no dietary restrictions or food allergies, were selected.

Three 2 h discussion groups, each with eight participants, were conducted. Participants were given a briefing on emotions and instructed to focus on how the sensory experience of the milkshakes made them feel during consumption. A warm-up activity was conducted to clarify what constitutes an emotion versus other conceptualizations. In the warm-up activity, each participant explained their emotional response to a picture they selected from a set of 30 pictures following Eaton et al. (2018) and Ng et al. (2013). Feedback was given to the participants during the activity to clarify where they used terms that were not emotions (i.e., how the picture made them feel at that moment), for example, "original."

Emotion terms were generated using triadic elicitation (Fransella & Bannister, 1977) where individuals were requested to evaluate milkshake sample triads and explain an emotional response that was evoked similarly by two samples but not by the third. The three sensorially distinct vanilla milkshakes (Table 1) plus two commercial vanilla milkshakes (Anchor protein+ vanilla flavored milk

TABLE 1 Composition of model vanilla milkshakes.

	Composition (w/w %)			
Product	Fat	Sucrose	Stevia	Thickener
X	6	6	0	0.1
Y	0.1	4	0	0.1
Z	0.1	1	0.007	0.3

TABLE 2 Vanilla milkshake lexicon and associated reference products.

Attribute	Description	Reference products
Sweetness	Sweet taste stimulated by sugar	4% (w/w) A1 sucrose in water
Vanilla	Natural vanilla flavor with a chemical note	0.03% (v/w) vanilla and 0.12% (v/w) vanilla cream flavors in water
Creamy flavor	Retronasal perception of creamy flavor	Fresh cream: 36.9% (w/w) fat (Anchor, New Zealand)
Creamy mouthfeel	In-mouth sensation of smooth, thick texture and moderate melting rate	Fresh cream: 36.9% (w/w) fat (Anchor, New Zealand)
Thickness	Resistance to flow in mouth	Vanilla custard (Anchor, New Zealand)
Mouthcoating	Anything that is coating/leaving a film in mouth after the swallowing, but not necessarily creamy	90% Full cream milk with 10% fresh cream (Anchor, New Zealand)
Astringency	The feeling of drying/lack of moistness resulting in friction throughout the mouth	2 g green tea (Dilmah Ceylon Green Tea, Sri Lanka) brewed in 400 ml filtered water at 100°C/10 min
Liquorice	Sweet and long lasting aftertaste	0.007% (w/w) stevia in filtered water

[Fonterra, New Zealand] and Nippy's vanilla flavored milk [Nippy's, Australia]) from the New Zealand market were used in this activity. The two additional products available in the market contained similar ingredients to the model milkshakes used in this study. Therefore, the additional two products were added to ensure a full list of emotion terms that could be felt with vanilla milkshakes were obtained. Two triads were randomly presented to each participant to ensure all participants had all five samples at least once. Aliquots of 30 ml of each sample were served at 15 ± 1°C. Participants were instructed to cleanse their palates using two to three sips of filtered water in between each sample tasting. At the end of triadic elicitation, participants discussed their responses as a group. The three discussion groups generated 58 emotion terms in total. Terms generated were combined with additional eight emotional terms identified in the literature relevant to food and beverages ("active," "accomplished," "adventurous," "affectionate," "aggressive," "angry," "daring," "determined" (Eaton et al., 2018; King & Meiselman, 2010; Ng et al., 2013)) resulting in 66 terms in total. Definitions for the emotion terms were established using a thesaurus (Microsoft Word Office 365). A much smaller number of items are generally used for TCATA attribute lists, typically around 10 (Castura et al., 2016; Pineau et al., 2012). Consequently, using a card sorting task, participants were asked to group emotion synonyms in the context of milkshakes to reduce the number of terms to a manageable list. This resulted in creating a set of the 12 key emotion terms participants felt most discriminated vanilla milkshakes (Table 3).

2.4 | Evaluation panel

A new consumer panel was recruited via the Feast consumer database and via emails to staff and students on the Massey University Palmerston North campus and residents of Palmerston North. Then, 104 volunteers ($n = 104$) (70% female) aged 19–65 years (mean age 32 years) who consumed milkshakes at least once a month, were not pregnant or lactating and not allergic to vanilla or dairy were selected to participate. Those who participated in the lexicon development groups were not selected for this panel.

TABLE 3 Final list of emotion terms and associated definitions used for TCATA of emotions.

Emotion term	Definitions
Satisfied	Filled with satisfaction
Comforted	Made comfortable (in a time of distress)
Happy	Enjoyment, joy or pleasure
Indulgent	I'm doing something I enjoy
Pleasant	Sense of likable satisfaction or enjoyment
Nostalgic	Happily reminded of familiar things or persons
Bored	Feel not interested in somebody/something
Disappointed	My hopes or expectations are not met
Disgusted	Repulsed
Relaxed	No strain or anxiety
Uncomfortable	Discomfort
Delight	Extreme pleasure or satisfaction

Abbreviation: TCATA, temporal check-all-that-apply.

2.5 | Product evaluations

Assessors profiled eight sips of each of the three milkshakes (served at 15 ± 1°C) using TCATA for sensory perception (*T_Sensory*), emotional responses (*T_Emotions*), and temporal liking (*T_Liking*). Eight sips of 15 ml each were chosen to represent a single serving portion of a flavored milk/milkshakes (120 mL) available in the market. Assessors were not informed that they were evaluating the same product over eight sips. Each "sip" (15 mL) was presented in a separate cup labeled with a different three-digit random code. Consumers took a forced 20 min break between each sample evaluation and were instructed to cleanse the palate with a bite of water cracker (Arnott's water cracker original, Australia) and filtered water to minimize carryover effects. No palate cleansing was performed between the eight sips of the same sample to mimic actual consumption experience.

T_Sensory, *T_Emotions*, and *T_Liking* evaluations were performed in three separate sessions, with consumers attending only one session per day with a minimum of 2 days between sessions. All three milkshakes were evaluated in each session of *T_Sensory*, *T_Emotions*, or *T_Liking*. The sessions were allocated to participants according to a randomized crossover design balanced for both presentation order and carryover effects (Schlich, 1993).

The TCATA technique was introduced to assessors during a familiarization session as detailed in Weerawarna N. R. P. et al. (2021). The response terms (sensory/emotions/liking) were presented to assessors on iPads using Compusense Cloud (Compusense Inc, Guelph, Canada). Immediately prior to data collection in each session, consumers were given a practice sample to familiarize themselves with the process (Jaeger et al., 2017). After familiarization, consumers evaluated each of the three milkshakes. Assessors clicked the start button immediately on placing the first sip in-mouth ($t = 0$ s). Assessors were prompted to swallow the sample at $t = 8$ s in each sip and the evaluation continued until $t = 20$ s for each sip. They were then prompted to take the next sip and the process continued until they finished all eight sips. The prompt "Take a sip" appeared on screen for 5 s after each sip. The total time for evaluation of eight sips of one vanilla milkshake sample was 195 s.

Sensory and emotional response terms, but not liking phrases, were randomized across assessors according to a balanced William Latin Square design to avoid attribute position and order related confounding effects and presented in two columns on screen. Response term order, however, was fixed for a given assessor for all the sample evaluations (Meyners & Castura, 2016). Assessors were instructed to select the terms that described the sensory characteristics, their emotional responses to or liking of the sample at the given time throughout the evaluations.

For *T_Sensory* evaluation, assessors used the TCATA approach to select relevant attributes (Table 2) perceived in real time during each of eight sips of each sample.

For *T_Emotions* evaluation, assessors were provided the list of 12 emotion terms and their definitions. Each emotion term was explained with an imagined example (e.g., "Happy - as you would feel when you receive a gift"). Additionally, they were given the opportunity to further clarify any of the terms or definitions as required prior to sample evaluation. The panel then used the emotion lexicon (Table 3), to evaluate the milkshakes over eight sips of each sample using TCATA but, instead of "attributes" perceived, consumers were instructed to select the emotions evoked as they consumed the sample. In both *T_Sensory* and *T_Emotions* evaluations, selected terms were programmed to fade away after 8 s and assessors were instructed to reselect the attributes if they were still detected. A fading time of 8 s was established during a pilot study which also enabled assessors to reselect emotions still felt initially and after swallowing the sample at 8 s (Weerawarna N. R. P. et al., 2021).

For *T_Liking*, using points on a traditional 9-point hedonic (like extremely, like very much, like moderately, like slightly, neither like nor dislike, dislike slightly, dislike moderately, dislike very much and dislike extremely), assessors were asked to select the level of liking that best described their response at the start of consumption and, if that changed, to select the new appropriate level and so on until the end of the evaluation period.

The start and stop times for each attribute, emotion term and level of liking were recorded for each sample using 0.01 s time slices.

2.6 | Data analysis and visualization

Statistical analyses were performed using R software, version 4.0.0 (R Core Team, 2020) in RStudio (2019) with $\alpha = .05$, unless specified otherwise. Package dplyr (Wickham et al., 2020) was used for data handling. Mean citation proportions for all sensory attributes were calculated for each *product* and *sip*. Temporal curves for *T_Sensory*, *T_Emotions*, and *T_Liking* were constructed to visualize the dynamics of mean citation proportions for sensory, emotion, and liking responses for each product for each of the five within-sip time points across the eight sips using ggplot2 package (Wickham, 2016). *T_Liking* curves were constructed using liking data collapsed into three categories: like (like extremely to like slightly), dislike (dislike slightly to dislike extremely) and neither like nor dislike (neither L/D) for simplicity of presentation and to facilitate subsequent data analysis relating liking to emotional and sensory descriptors (Section 2.6.2).

2.6.1 | Data modeling for temporal sensory responses

For each attribute, a GLM with default functions (function = glm, family="binomial," link = logit) (Montgomery et al., 2012) was used to model citation proportions across four-factors, *assessor* as a random factor and *product* (three milkshakes X, Y, and Z), *within-sip* (five time points 3, 7, 11, 15, 19 s within a 20 s evaluation time per sip) and *sip* (eight sips) as fixed factors with three-way interactions to investigate differences in the temporal sensory profiles of the products across sips. analysis of deviance (González Chapela, 2013; Montgomery et al., 2012) was applied following Weerawarna N. R. P. et al. (2021) to determine which main and interaction effects were statistically significant. Post hoc tests were used for pairwise comparisons. Holm's adjusted significance levels (Holm, 1979; Wright, 1992) for citation proportions across the *products* and *sips* were used where significant main effects existed (Shaffer, 1995).

2.6.2 | Data modeling associations between temporal sensory and affective responses

To understand associations between temporal sensory profiles and affective responses, the frequencies for selecting any possible combinations of *T_Sensory*, *T_Emotion*, and *T_Liking* responses were calculated for each *product*, *within-sip* and *sip* to create a new data matrix for analysis. Nine levels of liking led to some combinations having very small counts. Consequently, the liking data were collapsed into three categories liking, dislike and neither L/D.

A six-factor (*T_Sensory*, *T_Emotions*, *T_Liking*, *product*, *within-sip* and *sip*) GLM with default functions (function = glm, family="poisson," link="log") (Agresti, 2018b; McCullagh & Nelder, 1989; Montgomery et al., 2012) was then used to model the frequencies in this data matrix (i.e., frequencies in the data matrix were considered the predicted independent variable in the model). Next, an analysis of deviance (González Chapela, 2013; Montgomery et al., 2012) was used to determine which main and interaction effects were statistically significant in the model (Weerawarna N. R. P. et al., 2021) to investigate associations between temporal sensory and affective responses. Significant main effects and interaction terms were derived using the step() function and only significant terms were considered for analyzing associations across sensory, emotions and liking. Associated interaction plots were created to visualize observed responses for relevant experimental and statistical effects.

2.6.3 | Identifying specific sensory attributes associated with affective responses and sips

To determine which specific sensory attributes were related to which emotions or level of liking across sips, all significant two-way interactions were further analyzed. The number of citations across the two factors involved in the significant interaction was aggregated and the associated standardized residuals were derived from the GLM model producing two-way contingency tables to which Pearson's Chi-square tests for independence were applied. Bonferroni adjustment was used to obtain the critical value for each two-way interaction (Agresti, 2018a). Where three-way interactions included a *product* effect, similar two-way contingency tables were created for each *product* and analyzed for each two-way interaction. If a sensory attribute is revealed to be cited significantly more than expected by chance (represented by a positive value) for a level of liking or for an emotion, that specific sensory attribute is driving the level of liking or feeling of the emotion in the respective product experience or at a specific sip number. Similarly, negative values represent responses cited significantly less than expected by chance.

3 | RESULTS

Data analysis investigated the effects of within-sip and across sips variations of temporal responses for each product. However, although analysis of deviance models showed significant *within-sip* main effects, and in some instances significant two-way interactions involving the *within-sip* factor, both the main effects and the interactions were marginal. As an example, for thickness, although the effect size between products was larger at latter time points this difference was minimal (Figure 1). Product Y had lower within-sip citation proportions than products X and Z but the size of difference was small and deemed not important. The impact of within-sip effects overall were not considered meaningful for perception of these products and consequently are not discussed further in this manuscript. Subsequent analysis focused on the effects of multiple sips and product on temporal responses.

3.1 | Product profiles

3.1.1 | Temporal sensory product profiles

Figure 2 presents the TCATA curve by milkshake over eight sips for sensory attributes highlighting significant differences for attribute selection across sips overall. Table 4 provides a summary of deviances and p values from the GLM three-factor analysis of deviance on the citation proportions of sensory attributes across multiple sips. analysis of deviance showed significant *product* effects for all attributes (Table 4) indicating products had different temporal sensory profiles. Generally, sweetness, mouthcoating, thickness, creamy flavor and creamy mouthfeel were cited more for X than Y and Z (Figure 2). In comparison to X, Y and Z received higher citations for astringency. Additionally, vanilla was cited more for Y and liquorice for Z.

Statistical analysis revealed a significant *sip* effect on all attributes except creamy mouthfeel and thickness (Table 4), indicating variations in attribute citation across sips. Furthermore, citation variations for creamy mouthfeel, mouthcoating, and astringency across sips were unique for products (significant *product: sip* interactions, Table 4). This result emphasized that temporal sensory profiles across sips were product and attribute specific. For example, higher citations of mouthcoating for Y at sips 6 to 8 were differentiated from lower citations for the remaining sips (pair-wise comparison data not shown). For Z, only a higher citation for mouthcoating at sip 5 was differentiated from the other sips. Mouthcoating of X was not differentiated across sips. In fact, the pairwise comparisons revealed significant build-up of mouthcoating for Y and Z across sips, but not for X.

3.1.2 | Temporal liking profiles of products

Figure 3 presents the temporal liking curves by milkshake over eight sips. Table 5 provides a summary of key statistics for significant main effects and significant interactions from the GLM six-factor analysis of deviance on the frequency of selecting all possible combinations of temporal sensory, emotion and liking responses across eight sips of the products. Each product had unique temporal liking profiles (significant *product:T_Liking* interaction, Table 5). analysis of deviance of the

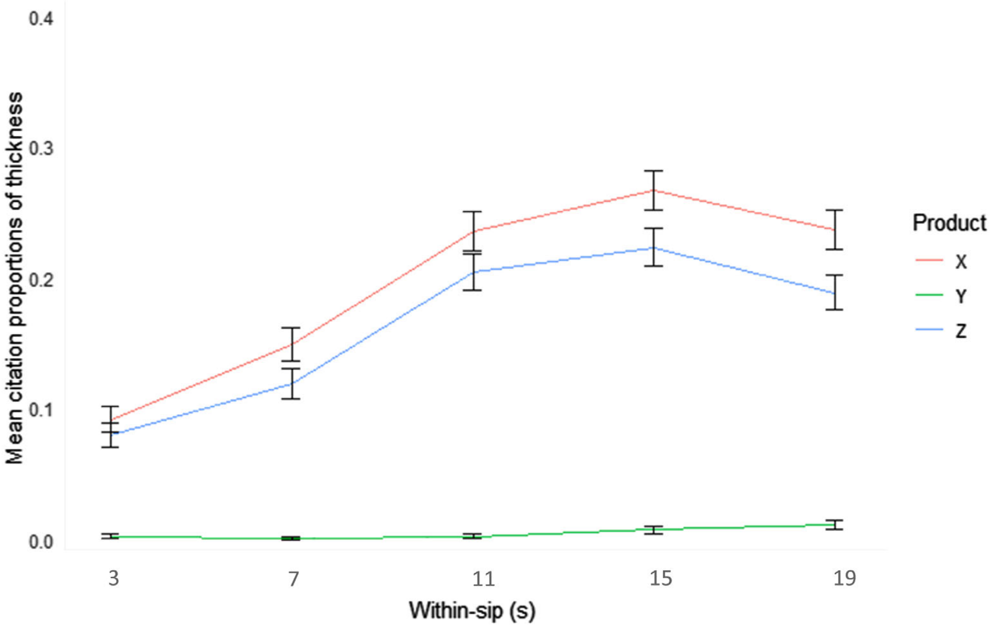

FIGURE 1 Mean citation proportions and standard error of thickness across within sip time points by product.

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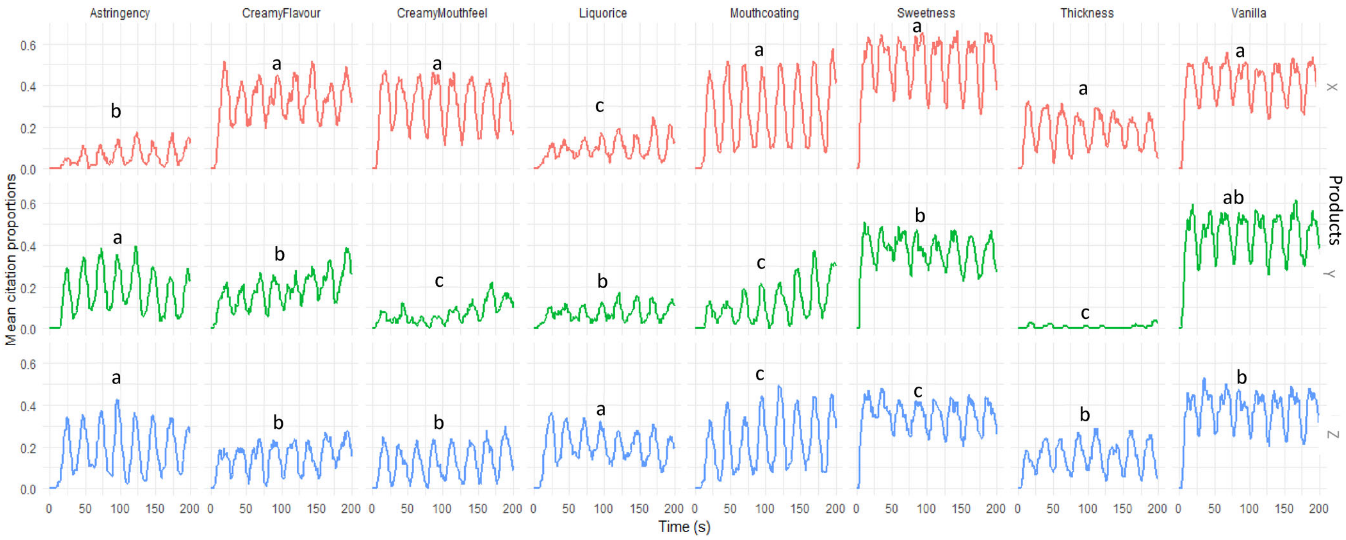

FIGURE 2 Temporal check-all-that-apply (TCATA) curves for each sensory attribute over eight sips (left to right across columns dynamics of the attribute across eight sips) by milkshake (products X, Y, and Z from top to bottom in rows). Y axis (mean citation proportions) and X axis (time for evaluating eight sips) are presented per sensory attribute by product. "abc" citation proportions with different letters within each attribute are significantly different across products on average (Holm's, $p < .01$).

six-factor model showed a significant *product:T_Liking:sip* three-way interaction (Table 5) confirming the product specific variations of *T_Liking* across sips. Pearson's Chi-square analysis showed, X was significantly disliked at sip 1, but liked by sip 3 to 4 with liking tailing off toward sip 8 (Table 6 and Figure 3). For Y, liking significantly decreased from sip 1 to 2. By sip 5, Y was neither L/D by the panel (Table 6 and Figure 3). In comparison, Z was significantly liked more at sip 1. A reduction of liking for Z was noted at sip 3 leading to dislike by sip 4. By sip 8, panelists significantly neither L/D Z indicating a reduction of dislike (Table 6 and Figure 3).

3.1.3 | Temporal emotional profiles of products

Figure 4 presents TCATA curves by milkshake over eight sips for each emotion. There was a significant *T_Emotions:product* interaction in the combined model, indicating that each product had different temporal emotion profiles (Table 5). Generally (over all sips), X received higher citations for positive emotions than Y and Z (Figure 4). Y and Z were cited more often for neutral/negative emotions. Pearson's Chi-square analysis revealed that on average, positive emotions "comforted," "delighted," "happy," "indulgent," "nostalgic," "pleasant," "relaxed," and "satisfied" were cited significantly more often for X. Negative or neutral emotions "bored," "disappointed," "disgusted" and "uncomfortable" were cited less often for X and vice versa for Z (Table 7).

Notably, emotional responses varied across sips (significant *T_Emotions:sip* interaction, Table 4). Generally, "delight," "happy," and "pleasant" were driving the product experience at sip 1 and "disgusted" by sip 3 to 4. "Nostalgic" drove the product experience by sip 6,"uncomfortable" by sip 7 and "relaxed" and "satisfied" by sip 8. "Bored" was significant in the product experience from sip 6 to 8 (Table 8). Temporal emotion curves across multiple sips also showed product specific variations. For example, citation changes across sips for "nostalgic" and "indulgence" appear to be driven by X (Figure 4). However, these variations were not significant in the combined model (Table 5), indicating analysis of the *T_Emotions* data on its own may provide further insights to understand dynamics of emotion responses, but such analysis was beyond scope for this manuscript.

3.2 | Associations between temporal sensory and liking responses

Temporal changes in liking responses were associated with particular temporal changes in sensory attributes. analysis of deviance of the five-factor combined model showed significant *T_Sensory:T_Liking* and *product:T_Sensory:T_Liking* interactions, indicating associations of *T_Sensory* and *T_Liking* were product specific. Pearson's Chi-square analysis showed, for X, dislike was selected significantly more often when liquorice was also selected. However, liquorice was not expected to be perceived in X as the formulation did not contain stevia. Dislike for X was less when vanilla was selected (Table 9). These associations to dislike with liquorice and vanilla emphasized the disliking of X was driven by its liquorice perception. For Y, when astringency, sweetness and vanilla were selected, selection of dislike increased, indicating that temporally these attributes were significant drivers of disliking of Y. Conversely, creamy mouthfeel drove temporal differences in liking of Y. However, at sips where creamy flavor was cited, Y was given more citations for neither L/D and less for dislike, hence creamy flavor was not a significant driver for temporal changes in liking or disliking for Y. For Z, the panel selected dislike more often when citing liquorice, sweetness and thickness more, indicating three

TABLE 4 Summary of p values and deviances from a GLM four-factor analysis of deviance for citation proportions of sensory attributes on selected time slices by the consumer panel. Bold font represents significant terms ($p < .05$).

	Sweet		Vanilla		Creamy flavor		Creamy mouthfeel		Thick		Mouthcoating		Astringent		Liquorice	
	Deviance	p	Deviance	p	Deviance	p	Deviance	p	Deviance	p	Deviance	p	Deviance	p	Deviance	p
Assessor (df = 103)	5106.816	**<.001**	5060.134	**<.001**	2337.004	**<.001**	1280.201	**<.001**	2193.731	**<.001**	1648.646	**<.001**	1470.377	**<.001**	1626.726	**<.001**
Within-sip (df = 4)	476.006	**<.001**	503.804	**<.001**	241.812	**<.001**	408.324	**<.001**	262.035	**<.001**	445.408	**<.001**	384.372	**<.001**	122.389	**<.001**
Sip (df = 7)	46.584	**<.001**	57.758	**<.001**	51.030	**<.001**	10.741	.213	25.847	**.001**	148.156	**<.001**	170.148	**<.001**	79.284	**<.001**
Product (df = 2)	348.517	**<.001**	69.250	**<.001**	507.459	**<.001**	1040.159	**<.001**	1442.172	**<.001**	366.864	**<.001**	379.639	**<.001**	371.474	**<.001**
Within-sip:Sip (df = 28)	512.646	**<.001**	545.650	**<.001**	211.181	**<.001**	189.839	**<.001**	123.997	**<.001**	574.269	**<.001**	302.538	**<.001**	183.991	**<.001**
Within-sip:Product	19.826	**.011**	3.761	.878	28.360	**<.001**	38.729	**<.001**	12.354	.136	9.020	.341	13.724	.089	4.720	.787
Sip:Product	13.039	.523	5.535	.977	27.891	.063	66.281	**<.001**	28.038	.064	45.902	**<.001**	40.379	**<.001**	13.645	.476
Within-sip:sip:Product	31.5	.996	18.354	.999	56.558	.076	36.111	.961	0.000	>.999	46.978	.403	32.361	.988	39.576	.774

Abbreviation: GLM, generalized linear model.

temporal sensory drivers of dislike for Z. Z received increased liking citations when creamy flavor and creamy mouthfeel were cited and hence are likely temporal drivers of liking for Z (Table 9). Therefore, it is evident that higher citations for liquorice, sweetness and thickness of Z influenced panel dislike of the product more than X and Y. In both Y and Z, despite lower citations temporal changes in creamy mouthfeel and creamy flavor were associated with temporal changes in liking by the panel. Although X received higher citations for both attributes overall, liking for X was more driven by the occurrence of liquorice s.

3.3 | Associations between temporal sensory and emotional responses

Analysis of deviance showed significant *T_Sensory:T_Emotions* association but no interaction with *product* (Table 5), emphasizing that the impacts of temporal sensory responses on temporal emotional responses were not product dependent. Figure 5 displays the interaction plot of *T_Sensory* and *T_Emotions*. Generally, lower citations of astringency and liquorice were reported alongside higher citations of positive emotions, for example "comforted," "happy," "delighted," "indulgent," "relaxed," and "satisfied." Higher citations of astringency and liquorice were reported with negative emotions "disgusted," "disappointed," and "uncomfortable." Therefore, incidences of higher citations of astringency and liquorice either simultaneously or individually were identified as drivers for evoking less positive and more negative feelings across sips during consumption of the milkshakes.

Some sensory attributes were significantly associated with, and therefore also identified as driving emotional responses to the products. Pearson's Chi-square analysis showed, on averaged sips, both astringency and liquorice were cited more often when negative emotions "disgusted," "disappointed," and "uncomfortable" were selected. Additionally, astringency was cited more often where "bored" was selected. Similarly, sweetness and vanilla were associated to some extent where "bored" was indicated. Sweetness was cited more alongside higher citations for "disappointed." Lower citations for "bored" and "relaxed" and higher citations for "uncomfortable" were observed where thickness was selected. Therefore, higher citations of astringency, liquorice, sweetness, vanilla, and thickness were identified as temporal drivers of negative or neutral emotional experiences across sips of the products in general (Table 10). Positive emotions "comforted," "delight," "happy," "indulgent," "nostalgic," and "pleasant" were cited more often where liquorice was selected less (Table 10). Positive emotions were selected more where creamy flavor and creamy mouthfeel were cited and vice versa for negative emotions (Table 10). Therefore, creamy flavor and creamy mouthfeel appeared to be overall drivers for positive emotional experience across the milkshakes. Interestingly, the results showed no associations between mouthcoating and either negative or positive emotions, emphasizing mouthcoating was not a significant driver for emotional experience of these milkshakes.

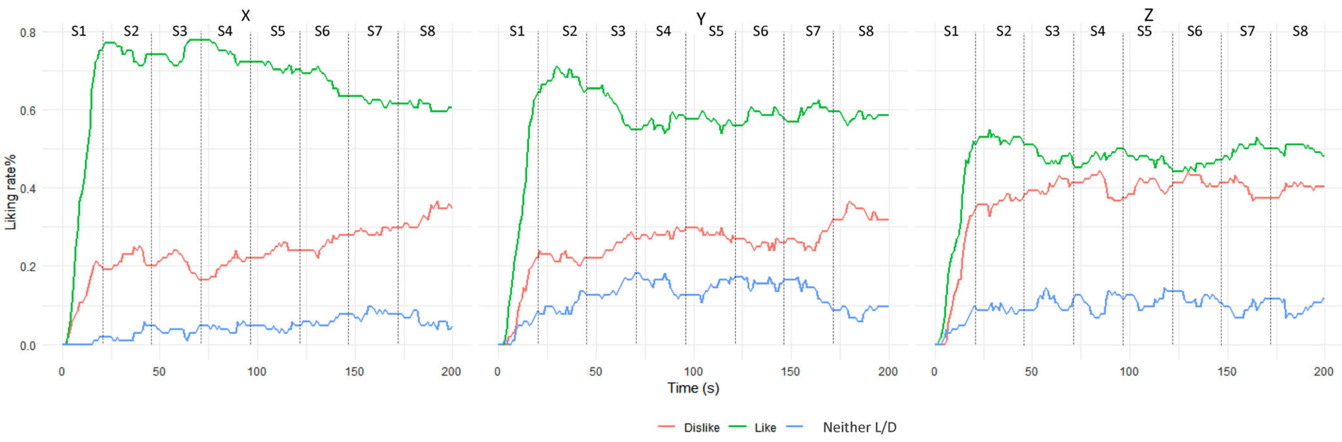

FIGURE 3 Temporal liking curves of products X, Y, and Z over eight sips (S1–S8).

TABLE 5 Summary of Pr(>Chi) values, deviances and related key statistics from GLM six-factor analysis of deviance for citations of temporal sensory, emotions, and liking responses on selected time slices over eight sips for significant main effects and significant interactions ($p < .05$).

	df	Deviance	Resid. df	Resid. dev	*p*-Value
Product	2	895.791	28,858	19,830.734	<.001
Within-sip	4	37.289	28,854	19,793.445	<.001
Sip	7	109.738	28,847	19,683.708	<.001
T_Sensory	7	868.399	28,839	18,815.308	<.001
T_Emotions	11	745.329	28,827	18,069.979	<.001
T_Liking	2	1393.645	28,818	16,676.333	<.001
Product:T_Liking	4	2612.559	28,800	14,063.774	<.001
T_Emotions:T_Liking	22	1387.761	28,693	12,676.013	<.001
T_Sensory:T_Emotions	77	1143.393	28,597	11,532.620	<.001
Sip:T_Liking	14	942.210	28,534	10,590.410	<.001
Product:T_Sensory	14	388.371	28,518	10,202.039	<.001
Within-sip:T_Sensory	28	423.425	28,486	9778.614	<.001
Product:T_Emotions	22	276.036	28,462	9502.578	<.001
Within-sip:T_Emotions	44	198.621	28,414	9303.957	<.001
Within-sip:Sip	28	130.438	28,386	9173.519	<.001
Within-sip:T_Liking	8	117.820	28,350	9055.699	<.001
T_Sensory:T_Liking	14	181.785	28,278	8873.914	<.001
Sip:T_Emotions	77	187.546	28,194	8686.367	<.001
Product:Sip	14	31.075	28,180	8655.293	.005
Product:T_Sensory:T_Liking	28	348.052	28,049	8307.241	<.001
Product:Sip:T_Liking	28	329.548	27,927	7977.693	<.001

Abbreviation: GLM, generalized linear model.

4 | DISCUSSION

4.1 | Associations between temporal sensory and liking responses

In general, temporal liking level was driven by the evolution of sensory attributes over time. Lower citations for creamy flavor and creamy mouthfeel of sips of Y and Z were related to changes observed in liking level. Higher citations of liquorice, sweetness, astringency and thickness across sips were linked to dislike of specific milkshakes. Perceived liquorice in X (although technically not present as Stevia was not present) and the sweetness of Z were significantly associated with dislike.

Research has previously indicated a relationship between sensory attribute dynamics and temporal liking through product evaluation on one (Ramsey et al., 2018; Thomas et al., 2015) or a few sips (Silva et al., 2018, 2019). By contrast, the present study used a multiple-sip evaluation approach which representing the consumption of a whole milkshake serving. *T_Liking* findings indicated that evaluation of at least seven sips were required to capture the significant drop in liking

TABLE 6 Pearson's Chi-square values for standardized residuals of *sip* and *T_Liking* by *product*.

	Product X (Chi-square = 2494.6, p < .001)			Product Y (Chi-square = 2201.6, p < .001)			Product Z (Chi-square = 1772.7, p < .001)		
	T_Liking								
Sip	Dislike	Neither L/D	Like	Dislike	Neither L/D	Like	Dislike	Neither L/D	Like
1	**5.122**	−**6.250**	−2.394	**4.761**	−**4.525**	**7.343**	−**4.408**	−**3.356**	**6.260**
2	0.275	−**4.537**	1.525	−**3.320**	−**3.904**	**5.621**	−0.487	−0.904	0.979
3	−1.857	−**3.873**	**3.282**	−0.758	−0.908	1.294	1.795	**3.268**	−**3.571**
4	−**3.372**	−2.966	**4.361**	1.852	**3.270**	−**3.867**	**4.183**	−2.506	−2.880
5	−1.735	−2.490	2.623	**3.447**	**5.969**	−**7.118**	−0.234	−2.577	1.622
6	−**3.620**	1.529	2.828	−0.065	1.973	−1.261	−0.555	2.522	−0.796
7	2.351	**9.547**	−**5.982**	−0.507	1.075	−0.260	1.782	−0.455	−1.557
8	**4.658**	**9.073**	−**6.981**	2.535	−**4.292**	0.576	−**3.338**	**3.250**	1.625

Note: Positive values = observed value − expected value, where observed > expected value. Negative values = observed value − expected value, where observed < expected value. Bold font represents significant associations (>Bonferroni adjusted critical value 3.077).

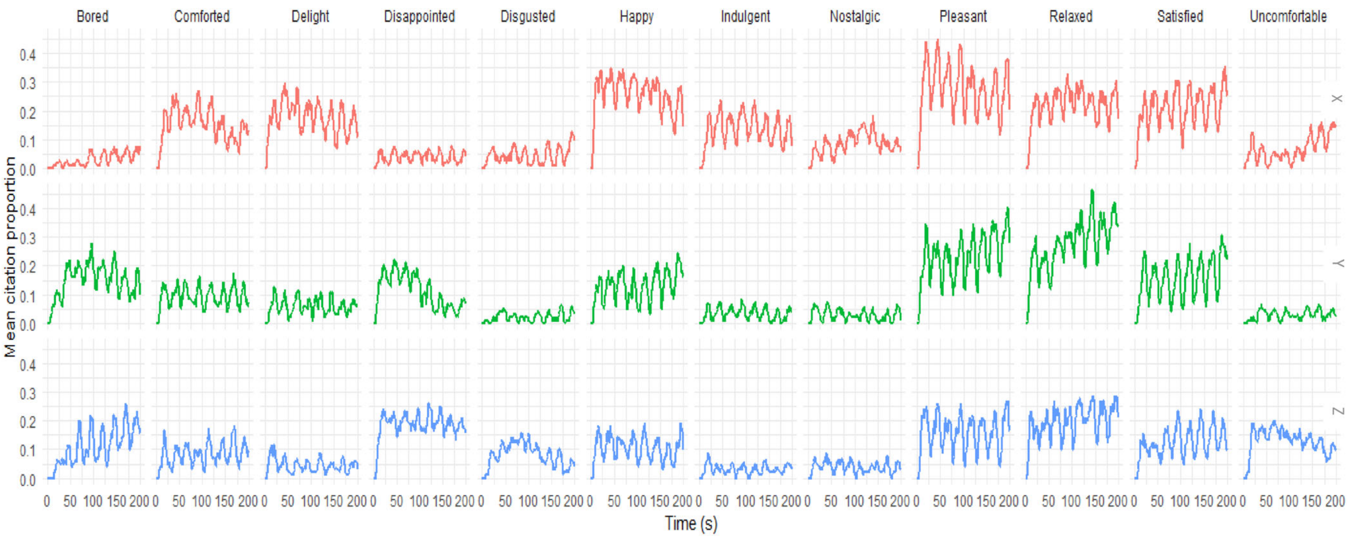

FIGURE 4 Temporal check-all-that-apply (TCATA) curves for emotion terms over eight sips (left to right across columns) by milkshakes (products X, Y, and Z from top to bottom in rows). Y axis (mean citation proportions) and X axis (time for evaluating eight sips) are presented per emotion term by product.

of X but drops in liking were evident at earlier sips for the other two products. Silva et al. (2018, 2019) used TDS and temporal liking for four sips capturing additional insights into the dynamics of perception and liking changes. However, the use of TDS by Silva et al. (2018, 2019) limited insights to only dominant sensations rather than the simultaneous dynamics of attributes that is shown to be obtained from TCATA in the present study.

4.2 | Associations between temporal sensory and emotional responses

Temporal emotion product profiles over multiple sips varied with respect to changes in temporal sensory profiles. Differences between temporal sensory products profiles are primarily driven by differences in product formulation. For example, product development technologists attempt to closely match the sensory profiles of products with noncaloric sweeteners like stevia to products sweetened with sucrose (Tan et al., 2019). The combined TCATA approach used here discriminated the two products with stevia versus sucrose identifying potential consequences for product acceptance or rejection and indicating the value of this combined whole product consumption TCATA approach for understanding temporal effects of using sugar replacers.

Jager et al. (2014), Lorido et al. (2019), and Silva et al. (2018, 2019) also showed associations between emotions and sensory response dynamics using TDE and TDS approaches in different product categories. However, the use of the dominance concept in TDE and TDS limited capturing information on the evolution of all

TABLE 7 Pearson's Chi-square values for standardized residuals of *product* and *T_Emotions* of average of sips.

	T_Emotions (Chi-square = 9910.7, $p < .001$)											
Product	Bored	Comforted	Delight	Disappointed	Disgusted	Happy	Indulgent	Nostalgic	Pleasant	Relaxed	Satisfied	Uncomfortable
X	**−39.467**	**14.901**	**30.216**	**−44.608**	**−14.980**	**23.265**	**29.082**	**14.997**	**7.229**	**−11.434**	**9.540**	**−21.581**
Y	**31.186**	**−4.764**	**−11.589**	**4.017**	**−14.022**	**−8.566**	**−14.491**	**−11.549**	**8.826**	**19.790**	0.283	**−17.850**
Z	**14.409**	**−11.994**	**−22.519**	**45.486**	**29.645**	**−17.673**	**−18.554**	**−5.757**	**−16.231**	**−5.881**	**−10.796**	**40.511**

Note: Positive values = observed value − expected value, where observed > expected value. Negative values = observed value − expected value, where observed < expected value. Bold font represents significant associations (>Bonferroni adjusted critical value 3.197).

TABLE 8 Pearson's Chi-square values for standardized residuals of *sip* and *T_Emotions*.

	T_Emotions (Chi-square = 894.58, $p < .001$)											
Sip	Bored	Comforted	Delight	Disappointed	Disgusted	Happy	Indulgent	Nostalgic	Pleasant	Relaxed	Satisfied	Uncomfortable
1	**−11.239**	1.325	**5.171**	−1.057	−3.401	**6.278**	−1.071	0.238	**7.870**	**−3.613**	−2.286	−2.678
2	**−7.057**	2.298	2.996	3.117	−0.516	3.347	1.401	0.210	2.905	**−6.054**	−2.935	0.980
3	−1.541	1.837	1.440	1.073	**4.942**	0.707	2.681	−2.504	0.982	**−3.951**	−2.082	−1.265
4	−0.793	1.949	−1.033	1.494	**5.442**	−0.531	2.010	−0.700	**−3.645**	−0.372	−0.632	−0.005
5	0.901	2.716	1.198	−0.192	0.011	−1.330	0.427	2.628	−3.326	2.233	−1.628	−2.161
6	**4.682**	−1.964	−3.261	−1.301	−2.930	−0.285	0.081	**3.799**	−2.090	2.431	1.202	−0.232
7	**6.104**	**−4.100**	−2.701	−0.676	**−3.852**	−1.925	−2.454	−1.540	−1.171	2.417	2.550	**4.777**
8	**7.699**	**−4.211**	**−3.721**	−2.825	−2.180	**−5.530**	**−3.547**	−2.121	−0.286	**6.780**	**5.797**	0.319

Note: Positive values = observed value − expected value, where observed > expected value. Negative values = observed value − expected value, where observed < expected value. Bold font represents significant associations (>Bonferroni adjusted critical value 3.470).

TABLE 9 Pearson's Chi-square values for standardized residuals of *T_Sensory* and *T_Liking* by *product*.

	Product X			Product Y			Product Z		
	(Chi-square = 199.28, *p* < .001)			(Chi-square = 291.8, *p* < .001)			(Chi-square = 369.29, *p* < .001)		
	T_Liking								
T_Sensory	Dislike	Neither L/D	Like	Dislike	Neither L/D	Like	Dislike	Neither L/D	Like
Astringency	1.432	2.021	−2.117	**3.084**	−0.886	−2.210	−0.300	2.571	−1.038
Creamy flavor	−1.106	−2.951	2.155	**−5.054**	**3.621**	2.151	**−9.592**	0.462	**9.584**
Creamy mouthfeel	−0.789	−1.132	1.173	−1.940	−2.803	**3.670**	**−11.719**	4.718	**9.537**
Liquorice	**10.691**	1.606	**−10.757**	**−3.375**	0.189	2.949	**4.795**	−0.501	**−4.649**
Mouthcoating	1.186	−0.973	−0.763	1.545	−2.442	0.248	2.286	−0.763	−1.942
Sweetness	0.507	3.399	−1.754	**3.238**	0.464	−2.355	**6.164**	−1.874	**−5.334**
Thickness	−1.092	−1.637	1.650	−2.699	0.407	2.185	**3.575**	−2.574	−2.316
Vanilla	**−3.346**	0.986	2.810	**4.303**	0.082	−1.244	−0.030	−0.347	0.213

Note: Positive values = observed value − expected value, where observed > expected value. Negative values = observed value − expected value, where observed < expected value. Bold font represents significant associations (>Bonferroni adjusted critical value 3.078).

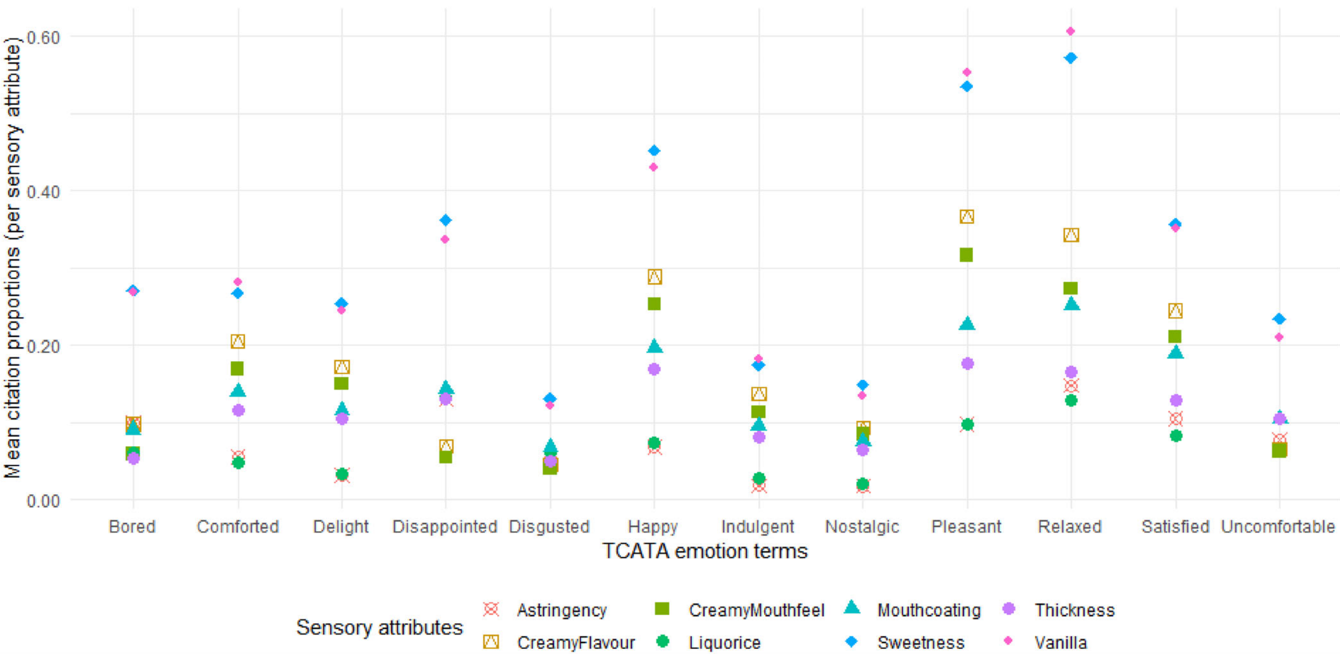

FIGURE 5 Mean citation of sensory attributes per attribute, by emotion term.

applicable sensory and emotional responses over time. Additionally, Jager et al. (2014) and Lorido et al. (2019) only used single intake product evaluation, which was later extended up to four sips by Silva et al. (2018, 2019). As such, the above studies do not fully account for the variation in the dynamics of sensory perceptions alongside emotional responses that would occur in actual product experience by a consumer.

Both temporal and static methods are used to measure emotional responses to products, and each have their own relative merits. The number of emotion terms that can be used in a TCATA or TDE approach to measure emotions is a key limitation in these temporal methods. A maximum of 10 attributes was recommended for TCATA (Castura et al., 2016), complying with the recommendation for TDS (Pineau et al., 2012). Researchers often measure emotional responses with larger lexicons, for example, EsSense profile with 39 emotion terms (King & Meiselman, 2010) with static methods such as rate all that apply (RATA) or check all that apply (CATA) (Ng et al., 2013). The use of the EsSense profile with a longer list of emotions provides descriptive overviews of the emotion profiles of the products. Such details will be useful to capture insights at early stages of product concept development or to obtain insights into when using ingredient substitutes. However, the use of static methods will be at the cost of understanding temporal aspects of the emotional responses.

TABLE 10 Pearson's Chi-square values for standardized residuals of *T_Sensory* and *T_Emotions*.

T_Sensory	*T_Emotions* (Chi-square = 4484.1, $p < .001$)											
	Bored	Comforted	Delight	Disappointed	Disgusted	Happy	Indulgent	Nostalgic	Pleasant	Relaxed	Satisfied	Uncomfortable
Astringency	**9.938**	−3.378	**−6.471**	**11.090**	**6.144**	**−6.479**	**−7.103**	**−4.997**	**−5.222**	1.396	2.119	**5.411**
Creamy flavor	**−5.259**	**4.873**	**4.014**	**−14.475**	**−5.972**	**4.132**	**4.514**	1.950	**5.795**	1.586	3.062	**−9.401**
Creamy mouthfeel	**−8.771**	**4.114**	**4.563**	**−13.329**	**−5.112**	**4.865**	**3.932**	2.427	**6.181**	−0.034	**3.651**	**−7.261**
Liquorice	1.722	**−4.354**	**−5.623**	**11.968**	**9.158**	**−5.119**	**−4.149**	**−3.961**	**−4.781**	−0.901	−1.445	**12.588**
Mouthcoating	−2.480	0.921	0.034	0.140	1.689	−0.568	1.695	2.064	−2.434	−1.068	1.877	0.323
Sweetness	**4.993**	−3.212	−0.494	**4.606**	0.068	0.268	−2.145	−0.016	−1.089	−0.373	−2.963	1.327
Thickness	**−5.731**	1.742	2.552	2.582	0.605	1.249	2.443	2.673	−2.492	**−5.122**	−1.280	**4.655**
Vanilla	**4.966**	−1.389	−1.263	2.652	−1.382	−1.319	−1.127	−1.751	0.667	2.985	−3.127	−1.390

Note: Positive values = observed value − expected value, where observed > expected value. Negative values = observed value − expected value, where observed < expected value. Bold font represents significant associations (>Bonferroni adjusted critical value 3.470).

A reduced emotion lexicon of 12 terms related to the model milkshake system was developed and used for this research. Other research has been conducted with reduced and product specific emotion lexicons. For example, Nijman et al. (2019) used a product specific emotion lexicon with 10 emotion categories with RATA, complying to the recommendations of Eaton et al. (2018). Silva et al. (2018, 2019) used most representative 10 emotion terms (reduced from a lexicon of 25 terms) related to products in TDE. However, application of RATA (Nijman et al., 2019) only provided static emotional profiles and TDE (Silva et al., 2018, 2019) only captured the dynamics of dominant emotions. Using a TCATA approach, albeit with a reduced product specific lexicon, was advantageous to capture overall descriptive dynamics of the emotion profiles.

Investigating temporal emotions with a multiple-sip TCATA approach over whole product consumption will be useful closer to the end of product development/improvement stages or to descriptively match competitor products in the market. The results also suggested that feelings of boredom had begun to establish in the latter sips, despite the milkshakes evoking "relaxed" and "satisfied" feelings. Further, there were variations in citations of sweetness and astringency across sip. Additionally, "bored" was associated with sweetness and astringency. In fact, the dynamics of sweetness and astringency may have contributed to the development of boredom toward latter sips. This may indicate that, in terms of sensorial enjoyment, a reasonable serving size had been met for this product type and highlights the additional value of this approach in identifying appropriate product serving sizes. This may be particularly important in understanding compliance with nutritional supplements, for example. Feelings of nostalgia have been reported on initial bite/sips for some products (e.g., flavored dark chocolate (van Bommel et al., 2019)) and beer (Nijman et al., 2019) but not for others (e.g., dark chocolate (Jager et al., 2014)). For milkshake it appears nostalgia takes time to develop (i.e., by sip 6) and highlights the need for multiple sip studies to understand all emotions evoked by product consumption experiences.

The sensory attributes associated with emotions were also associated with temporal liking, indicating links between temporal emotions and liking responses. Higher citation of sweetness, astringency, and liquorice in sips linked to feelings of more negative or neutral emotions for milkshakes. The same three attributes, when cited higher, were associated with disliking of sips across the milkshakes. Similarly, creamy flavor and creamy mouthfeel, which associated with positive emotions were also associated with liking of the milkshakes when lower citations were given. Mouthcoating was not contributing to any important extent for the liking nor emotional experience of these milkshakes. Therefore, it is evident that here emotional experience, where related to valence, was associated with level of liking of milkshakes and vice versa. However, temporal emotion measures provided wider descriptive associations to sensory attributes as opposed to a measure of attribute liking. For example, as revealed by the results, lower citations of creamy flavor and creamy mouthfeel were associated with liking Y and Z. Higher citations of creamy flavor or creamy mouthfeel of X were not significantly associated with liking nor disliking. However, the two attributes were identified as driving positive emotions toward milkshakes. Similarly, links between emotional and liking responses were reported by Ng et al. (2013) and Nijman et al. (2019) for static emotions and overall liking responses and Lorido et al. (2019) and Silva et al. (2018, 2019) for dynamics of dominant emotions and temporal liking responses. Therefore, measuring temporal emotions of products in addition to temporal liking will capture more detailed insights into consumer product experience.

Liking and emotion were measured using different types of measure namely a nine-point scale and CATA, respectively. It is possible that this difference may impact the ability of these measures to discriminate products and further research to test this hypothesis is warranted if comparing the discriminability of liking versus emotional response. It is also important to note that experimental practicalities led to the sensory, emotion and liking data being collected in different sessions to not compromise ethical issues related to sample volume/nutrient consumption but is noted as a limitation. Ideally, all three evaluations of sensory, emotion and liking for a product would be performed in the same session and should be considered for future work in this area. It is possible that even more associations between the different responses would be highlighted had that been the case. Furthermore, within-sip effects were found to be marginal on temporal drivers of liking and emotional responses according to this product set indicating a CATA by sip approach may have revealed similar findings. However, use of a TCATA approach and data analysis with *within-sip* effect would be beneficial in other product matrices where more dramatic sensory changes occur within a sip/bite and over multiple sips, such as solid foods, for example, ice cream or alcoholic beverages.

5 | CONCLUSIONS

The TCATA approach enabled associations between citation patterns in temporal sensory responses and temporal emotional and liking responses throughout the whole product consumption experience to be identified. Associations between temporal sensory and emotional responses identified specific drivers of emotional experience to the products which are likely to lead to product acceptance or rejection. The same sensory attributes were associated with both emotions and liking responses indicating a relationship between the emotional experience and liking/disliking a product, although emotional association highlighted additional insights beyond the liking data.

Moreover, findings varied depending on product. Having used three products in this experiment, due to cost and time constraints, the findings cannot be generalized to all milkshakes or all product categories, and further research will be required to compare the applicability of these findings with respect to other product categories.

Assessors in this study were the frequent consumers of milkshakes/flavored milks but nothing was known about their past experiences with such products which could impact their emotional response. Capturing the nature of assessor milkshake experiences may provide further understanding of the relationship between personal experiences and emotional responses to food.

Temporal responses varied over multiple sips, which highlighted the essential nature of multiple-sip product evaluations when the objective is to capture insights into the impact of whole product experiences. It is important to predetermine the reasonable number of sips for that particular beverage. For example, determining the number of sips to deliver that beverage's recommended portion size. This may be particularly important when needing to deliver a certain amount of active compounds in a nutritional supplement, or serving sizes based on alcohol percentage in a beer/wine versus caloric value in a ready-to-drink milkshake. For this product set within sip variations of perception were marginal. With hindsight, CATA per sip would have been an appropriate methodology. Consequently, it is important for researchers to consider whether within sip measures are needed for specific product categories prior to method selection.

Use of TCATA limits the number of emotion terms that can be employed. However, the emotion lexicon was carefully preselected for this research and the TCATA approach enabled the link between temporal evolution of sensory attributes and affective response to be uncovered highlighting its potential for providing much deeper insights for product development and optimization and our general understanding of temporal perception and affective response.

AUTHOR CONTRIBUTIONS

Maheeka Weerawarna N. R. P.: Methodology, investigation, analysis, writing-original draft. **Ashling Ellis**: Methodology, supervision. **A. Jonathan R. Godfrey**: Methodology, analysis, supervision. **Joanne Hort**: Conceptualization, methodology, supervision, writing-review and editing, funding acquisition.

ACKNOWLEDGMENTS

The authors wish to acknowledge the Riddet Institute for financial support, Fonterra Co-operative Group Ltd. for materials and product preparation advice and Invita NZ Ltd. for provision of flavors. Open access publishing facilitated by Massey University, as part of the Wiley - Massey University agreement via the Council of Australian University Librarians.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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How to cite this article: Weerawarna N. R. P., M., Godfrey, A. J. R., Ellis, A., & Hort, J. (2023). Identifying temporal drivers of product acceptance and rejection across sips during whole product consumption. *Journal of Sensory Studies*, *38*(5), e12855. https://doi.org/10.1111/joss.12855