

Effect of sipping method on sensory response to single and multiple sips of vanilla milkshake using temporal-check-all-that-apply

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Abstract

Whether drinking from a cup versus through a straw effects sensory perception is inconclusive, as is whether such differences hold across and within multiple sips. This study aimed to determine if product profiles and product discrimination varied depending on whether a product was sipped from a cup or through a straw. An expert panel ($n = 9$) investigated differences in temporal profiles of six milkshakes across sipping methods. Temporal discrimination across eight attributes was analyzed on selected time slices, across eight sips using generalized linear model Analysis of Deviance. Sweetness, vanilla, astringency, and liquorice attributes were cited significantly more often sipping through a straw, however sipping from a cup showed more significant attribute discriminations across products. Attribute discrimination was increased across multiple sips compared to sip one. Multiple sip TCATA analysis showed significant effects of sipping method within-sips and over multiple sips emphasizing the effects of sipping method on multiple sip TCATA product discriminations.

Practical Applications

Milkshakes are often sold in bottles (enabling consumption either directly from the bottle or from a cup) or as on-the-go packs with a straw. This study showed that the sensory profile of milkshake varied depending on whether sipped from a cup or through a straw. However, often-sensory evaluations of beverages are performed by tasting from a cup. This indicates an important practical consideration in terms of sensory study design regarding evaluating products in the intended consumption format or formats. The findings also highlighted the importance of evaluating product volume (or weight) equivalent to single serving size to capture consumer experience closer to actual consumption occasions, as differences in response to one sip changed across multiple sips.

1 | INTRODUCTION

Sensory product experience is affected by the receptacle in which a beverage is served, such as a ceramic versus a glass cup (Raudenbush,

Meyer, Eppich, Corley, & Petterson, 2002; Spence & Wan, 2015), and if used, the diameter of a straw (Akiyama et al., 2012; Lin, Lo, & Liao, 2013) and straw material. Akiyama et al. (2012) showed increased flavor and aftertaste intensities of chilled coffee beverages

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with decreasing diameters of straws from 7.3 to 5 mm. Pramudya, Singh, and Seo (2020) showed liking of cold tea increased when sipped through a copper or stainless steel straw compared to a paper straw. Physical changes in drinking behavior such as sip time and flow rate (Lin et al., 2013), and changes in mass transfer of tastants in-mouth and oropharynx (Salles et al., 2010; Selway & Stokes, 2014) have also been reported to alter sensory perception due to changes in the drinking receptacle. Furthermore, Hashimoto, Inami, and Kajimoto (2008) highlighted the significance of pressure, vibration, and auditory cues in product experience when drinking through a straw using an audio-tactile straw-like user interface based on these cues to create a more natural auditory sensation of drinking with a straw. Many beverages can be consumed either via direct sipping from a cup/glass/bottle or via a straw but resulting variation in sensory perception has not been investigated.

Effect of receptacle on sensory perception has only been studied using single sip evaluations with static sensory techniques (Akiyama et al., 2012; Lin et al., 2013; Pramudya et al., 2020; Raudenbush et al., 2002; Spence & Wan, 2015). However, actual beverage consumption occasions generally occur over multiple intakes resulting in dynamic sensory perceptions (Hort, Hollowood, & Kemp, 2017). Progressive profiling evaluates multiple intakes/sips/bites by design (Jack, Piggott, & Paterson, 1994), however, other methods have been adapted to include multiple intake evaluations for a few sips or bites, for example time intensity (Guinard, Pangborn, & Lewis, 1986), sequential profiling (Methven et al., 2010) and temporal dominance of sensation (Silva et al., 2018). These studies revealed buildup of attribute perceptions over multiple sips, for example astringency in wine (Guinard et al., 1986; Silva et al., 2018).

TCATA (Castura, Antunez, Gimenez, & Ares, 2016) enables simultaneous evaluation of attributes. Panelists select and de-select attributes during the evaluation as they evolve. Citation proportions for each attribute are calculated and plotted against time to create TCATA curves. TCATA curves illustrate the dynamics of all product attributes of interest over time. Oliveira et al. (2015) applied a multiple sip TCATA approach to investigate the dynamics of sweetness, bitterness, and thickness of chocolate drinks. Weerawarna, Godfrey, Ellis, and Hort (2021) also highlighted the importance of multiple sip TCATA methodology to capture adaptation or buildup effects of milkshake attributes. Additionally, the researchers presented a novel approach to interpret dynamic TCATA data providing insights within a sip as well as across sips. TCATA provides an expedient opportunity to compare within-sip and across-sip attribute dynamics of a product using different ingestion methods used by the consumer or directed by packaging, for example, straws provided for drinking “on the go” beverage packs. Investigating the effects of sipping method in a manner closely representing actual consumption, that is, over multiple sips, may also provide closer insights into actual consumer product experiences.

Consequently, this study aimed to study the effects of cup versus straw sipping on TCATA sensory profiles of vanilla milkshake in terms of citation proportions and product discrimination at the first sip. Second, the consistency of sipping method effects on citation proportions

and product discrimination over multiple sips was also investigated. The composition of the milkshakes was varied in product formulations only to acquire a range of sensory experiences. The impact of product composition on temporal sensory profiles was out of scope for this study.

2 | MATERIALS AND METHODS

This study was evaluated by peer review and judged to be low risk via the Massey University Human Ethics Committee process (application ID 4000019630). All product preparation, panel training and sample evaluation was carried out in the Product Development and Sensory Testing Laboratory, at Massey University, Palmerston North campus, New Zealand.

2.1 | Panel

Seventy-six volunteers aged 18–55 from Massey University Palmerston North Campus and Palmerston North city completed a pre-screening questionnaire and three screening sessions according to ISO3972:2011(E); ISO5496:2006(E); ISO22935-1:2009(E) standards on general guidelines for expert sensory panel recruitment. Nine panelists (seven females; aged 26–52 [mean age 37 years]) were selected based on their sensory acuity and ability to articulate sensory attributes. The selected expert panel trained to evaluate vanilla milkshakes following a modified QDA approach (Weerawarna, 2021) was engaged to carry out product evaluations for this research. Assessors were offered a voucher as an inconvenience allowance for their time.

2.2 | Products

Six model vanilla milkshakes were developed to elicit a range of different sensory attributes with final product compositions as shown in Table 1. Sensory profiles determined by the panel using QDA and sipped from a cup in a previous study (Weerawarna, 2021) are shown in Table 2.

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) was mixed using a Thermomix (TM5, Vorwerk Electrowerke GmbH & Co. KG, Germany) in the Product Development Laboratory at Massey University Palmerston North campus.

Filtered water was heated to 60°C. The dairy ingredients and A1 sucrose were combined in the Thermomix set at 60°C, speed 2.5 for 5 min. The thickener blend and 60°C filtered water were mixed using a hand blender (Kenwood HDP306WH, China) at speed 1 for 2 min. The thickener mixture was then added to the Thermomix and

TABLE 1 Composition of model vanilla milkshake

Product	Abbreviations for milkshake formulation	Composition (w/w %)			
		Fat	Sucrose	Stevia	Thickener
P1	HFHSLT	6	6	0	0.1
P2	HFLSLT	6	4	0	0.1
P3	LFHSLT	0.1	6	0	0.1
P4	LFLSLT	0.1	4	0	0.1
P5	LFLSHT	0.1	4	0	0.3
P6	LFLSHT	0.1	1	0.007	0.3

Abbreviations: F, fat; H, high level; L, low level of each F, S, S ingredient; S, sucrose; S, stevia; T, thickener.

TABLE 2 Mean attribute intensity and observed SE scores of the milkshakes for panel-defined attributes at sip 1 from cup

Product	Sensory attributes															
	Sweetness		Vanilla		Creamy flavor		Creamy mouthfeel		Thickness		Mouthcoating		Astringency		Liquorice	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
P1	13.8 ^a	0.3	10.7 ^a	1.3	13.9 ^a	0.3	13.4 ^a	0.4	13.2 ^a	0.4	13.3 ^a	0.4	1.4 ^b	0.5	0.1 ^b	0.0
P2	10.3 ^{ab}	1.1	10.0 ^a	1.1	13.4 ^a	0.4	13.1 ^a	0.5	12.8 ^a	0.5	12.6 ^a	0.6	2.2 ^b	0.9	0.1 ^b	0.0
P3	11.0 ^{ab}	1.1	10.1 ^a	1.1	3.5 ^b	0.7	3.2 ^c	0.5	3.1 ^c	0.8	3.5 ^{bc}	0.7	8.0 ^a	1.2	0.5 ^b	0.2
P4	8.7 ^b	1.0	8.8 ^a	1.2	3.0 ^b	0.8	2.3 ^c	0.5	3.1 ^c	0.8	2.4 ^c	0.6	8.2 ^a	1.3	0.3 ^b	0.1
P5	7.0 ^b	1.0	8.4 ^a	1.0	4.9 ^b	1.0	5.4 ^b	0.9	5.5 ^b	1.0	4.5 ^b	0.8	8.3 ^a	1.4	0.2 ^b	0.1
P6	7.7 ^b	1.2	8.6 ^a	1.2	3.4 ^b	0.8	3.2 ^{bc}	0.6	4.7 ^{bc}	1.1	3.9 ^{bc}	0.6	8.2 ^a	1.3	13.5 ^a	1.0

Note: Data are means of nine panelists and SE of duplicate. Products: P1 (HFHSLT), P2 (HFLSLT), P3 (LFHSLT), P4 (LFLSLT), P5 (LFLSHT) and P6 (LFLSHT). The superscripts letters "abcd" indicates products within a column with different lowercase letters, are significantly different from each other on one sip from cup (Holms, $p < .01$).

combined with the dairy ingredients. The contents were heated to 90°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°C using an ice water bath (0°C) followed by addition of vanilla flavors using a pipette. The vanilla milkshakes were packaged in PET containers and stored under refrigerated conditions (5°C). Microbial testing confirmed that products were safe for human consumption for up to 4 days from preparation and all products were assessed within that period.

2.3 | Sensory lexicon development and expert panel training

A lexicon previously developed by the panel as described in Weerawarna (2021) was adopted (Table 3). The panel was previously trained to evaluate milkshake whilst sipping from a cup (15 mL served in 30 mL cup), further instruction was given on a protocol to sip (15 mL served in a 30 mL cup) through a 6 mm × 70 mm recyclable polypropylene (PP) white color straw (Davis Trading Ltd., Palmerston North, New Zealand). The straw was selected to represent take away straws served with milkshakes in New Zealand and was used in preliminary experiments conducted to determine a representative sip volume and sipping time for this study (data not shown). The panel was trained to

sip 15 mL through a straw without slurping to avoid ingestion of air. The TCATA protocol (Figure 1a) was introduced to the panel during a familiarization session. Eight attributes (Table 3) were presented to panelists using Compusense[®] Cloud on iPads. Attributes were randomized and presented in two columns on the iPad screen, according to a balanced William Latin Square design to avoid attribute position and order related confounding effects. However, attribute order was fixed for a given panelist for all the evaluations (Meyners & Castura, 2016). Panelists were instructed to sip the whole product volume in one intake and sample cups and straws were inspected after the evaluations to confirm this occurred. Thereafter, a multiple eight sip evaluation protocol was introduced to the panel (Figure 1b,c) with individual 15 mL sips served in eight separate 30 mL cups on a tray.

2.4 | Product evaluations

The panel evaluated the vanilla milkshakes ($n = 6$, $15 \pm 1^\circ\text{C}$) following the protocol in Figure 1 in duplicate for each sipping method; first from a cup (15 mL per sip × eight sips) and second through a straw (15 mL per sip × eight sips), over six 2 h sessions. Sample replicates were presented according to a balanced William Latin Square design and the panel evaluated four samples in each 2 h session. The panel

TABLE 3 Vanilla milkshake lexicon and associated reference products

Attribute	Description	Reference products ^a
Sweetness	Sweet taste stimulated by sugar	4% A1 sucrose in water
Vanilla	Natural vanilla flavor with a chemical note	0.03% vanilla and 0.12% 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% stevia in filtered water

^aReference products were developed based on ISO3972:2011(E) standards and in tandem with the panel.

were given a forced 20 min break between each eight-sip 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 normal consumption. Samples were evaluated in isolation in sensory booths at $21 \pm 1^\circ\text{C}$ under red light to mask visual differences between samples.

2.5 | Data analyses

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, François, Henry, & Müller, 2020) was used for data handling. TCATA data were analyzed following Weerawarna (2021) as detailed below.

2.5.1 | Effect of sipping method on sip one

To investigate the impact of sipping method on sensory profiles (citation proportions) of products and level of product discrimination on first sip, and then to compare if differences existed across multiple sips, sip one data were extracted and analyzed separately. Mean citation proportions and observed SE were calculated for each *sipping method* for each *product* and *within-sip* time points. Mean citation proportions were plotted against sample evaluation time (package `ggplot2` [Wickham, 2016]) for each sipping method at sip one for data visualization with TCATA curves. Generalized linear models (GLM) with default functions (`function = glm, family = "binomial", Link = Logit`) (Montgomery, Peck, & Vining, 2012) were used to model the citation proportions of the three factors (*sipping method, product and within-sip*) with three-way interactions for each attribute at sip one to investigate their effects on temporal sensory perceptions. Analysis of Deviance (González Chapela, 2013; Montgomery et al., 2012) was used to determine which main and interaction effects were statistically significant. Associated interaction plots were created to visualize observed responses against time for the relevant experimental effects and statistical effects. Posthoc tests were used to make pairwise comparisons of citation proportions among experimental factors for which there was a significant main effect (Shaffer, 1995). Holm's adjusted significance levels (Holm, 1979; Wright, 1992) were used to eliminate lack of independence in pair-wise comparisons.

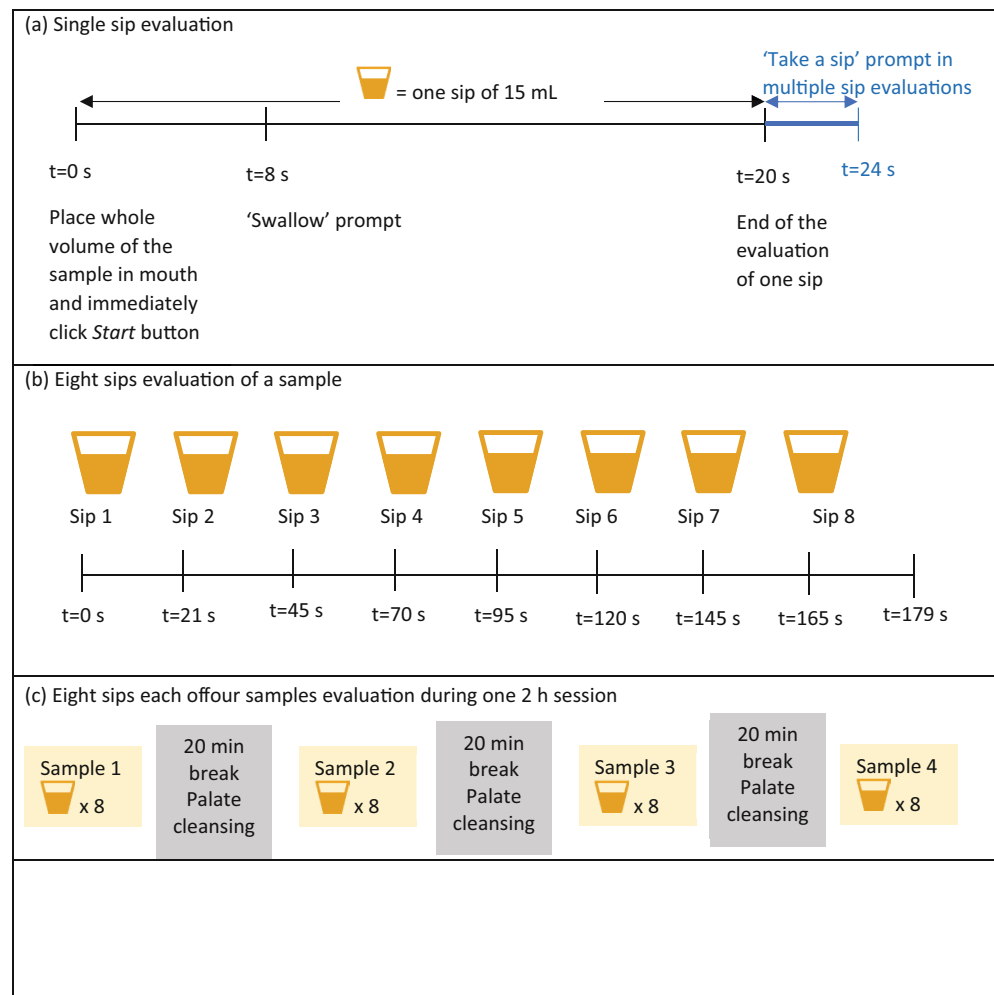
As a key objective of this study was to determine if sipping method impacted temporal sensory product profiles (citation proportions) and the level of discrimination between the products at sip one, each sipping method was also considered separately in this analysis. Data was split by sipping method and Analysis of Deviance was performed for each attribute using a two-factor (*product and within-sip*) GLM with two-way interactions for sip one data.

2.5.2 | Effect of sipping method on multiple sips data

Mean citation proportions were plotted against sample evaluation time (package `ggplot2` [Wickham, 2016]) for each sipping method across eight sips for data visualization with TCATA curves. Citation proportions across eight sips were also modeled using four-factor (*sipping method, product, sip and within-sip*) GLM with four-way interactions to investigate their effects on temporal sensory profiles across multiple sips. Analysis of Deviance, interaction plots and post hoc comparisons were performed as explained for sip one data in Section 2.5.1.

As a key objective of this study was to determine if sipping method impacted temporal sensory product profiles (citation proportions) and the level of discrimination between the products over multiple sips, each sipping method was also considered separately in this analysis. Data was split by sipping method and Analysis of Deviance

FIGURE 1 Sipping Protocol



was performed for each attribute using a three-factor (*product*, *sip* and *within-sip*) GLM with three-way interactions for multiple sip data.

3 | RESULTS

Figure 2 exhibits the TCATA curves and post hoc mean citation proportion comparisons of the milkshakes at the first sip by sipping method. Although the patterns are similar, visible differences are evident. Figure 3 shows the TCATA curves and post hoc mean comparisons across the multiple sips. Again, although similar patterns are observed for each sipping method, some differences can be observed. Table 4 lists the deviances and associated p values from the Analysis of Deviance for all the sensory attributes at sip 1 using a three-factor (*sipping method*, *product* and *within-sip*) GLM with three-way interactions. Table 5 summarizes the deviances and p values from Analysis of Deviance at sip 1 using two-factor GLM (*product* and *within-sip*) with two-way interactions, for each sipping method. Table 6 lists the deviances and associated p values from the Analysis of Deviance for all the sensory attributes across multiple sips using a four-factor (*sipping method*, *product*, *within-sip* and *sip*) GLM with four-way interactions. Table 7 summarizes the deviances and p values from Analysis of

Deviance across multiple sips using three-factor GLM (*product*, *within-sip*, and *sip*) with three-way interactions, for each sipping method. The findings are discussed below.

3.1 | Effects of sipping method on one sip data

3.1.1 | Sipping method and attribute citation frequency

At sip 1, attributes were generally cited more often when sipped through a straw than from a cup (Figure 2). Analysis of Deviance highlighted that the *sipping method* effect was significant for sweetness, vanilla, astringency, and liquorice (Table 4). Within the sip, the dynamics of citation proportions primarily followed a similar pattern in both sipping methods. However, there was a significant *within-sip* effect for all the attributes due to magnitude differences in citations across cup and straw. For example, mouthcoating has generally higher magnitude increments of citations after 8 s when sipped from a straw than from a cup (Figure 2, A5). Statistical analysis also highlighted a significant *within-sip:sipping method* interaction for creamy mouthfeel (Table 4). The interaction was primarily due to an increased

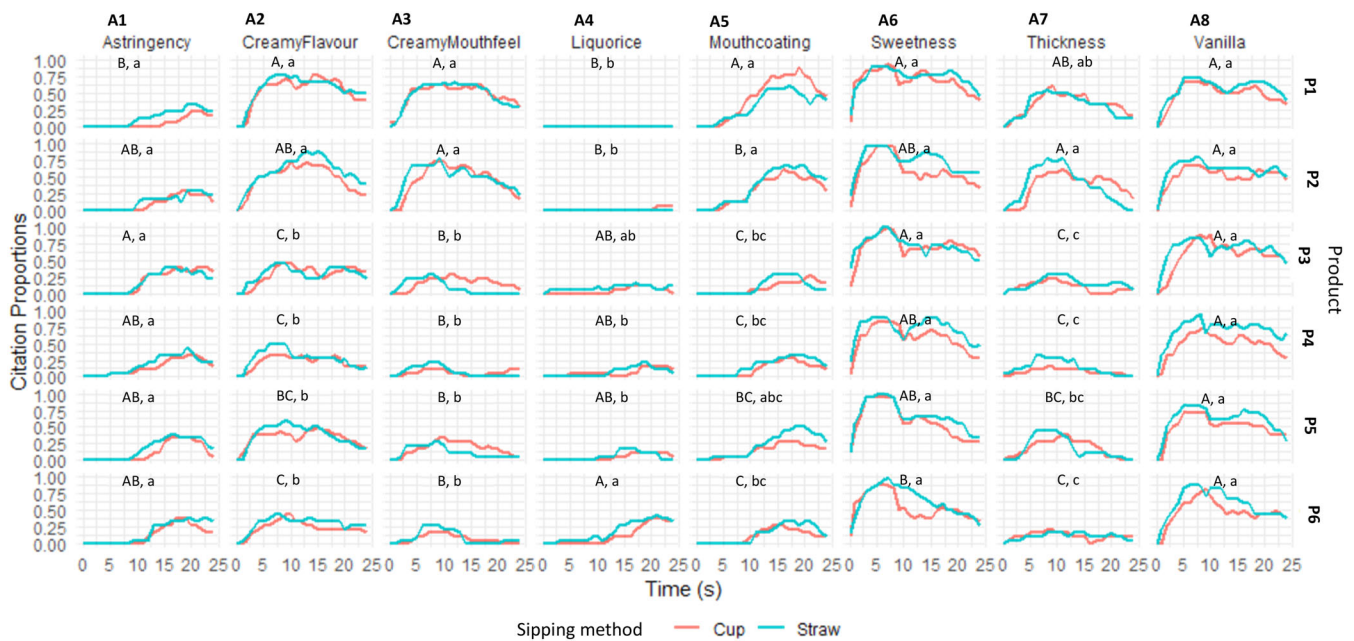


FIGURE 2 TCATA curves for sensory attributes (A1–A8 in columns) of milkshakes (P1–P6 in rows) by cup and straw sipping at the first sip. “ABC” (Citation proportions from cup) and “abc” (citation proportions through straw): different letter codes indicate significant attribute difference between products (Holm’s, $p < .01$). Products: P1 (HFHSLT), P2 (HFLSLT), P3 (LFHSLT), P4 (LFLSLT), P5 (LFLSHT), and P6 (LFLSSHT)

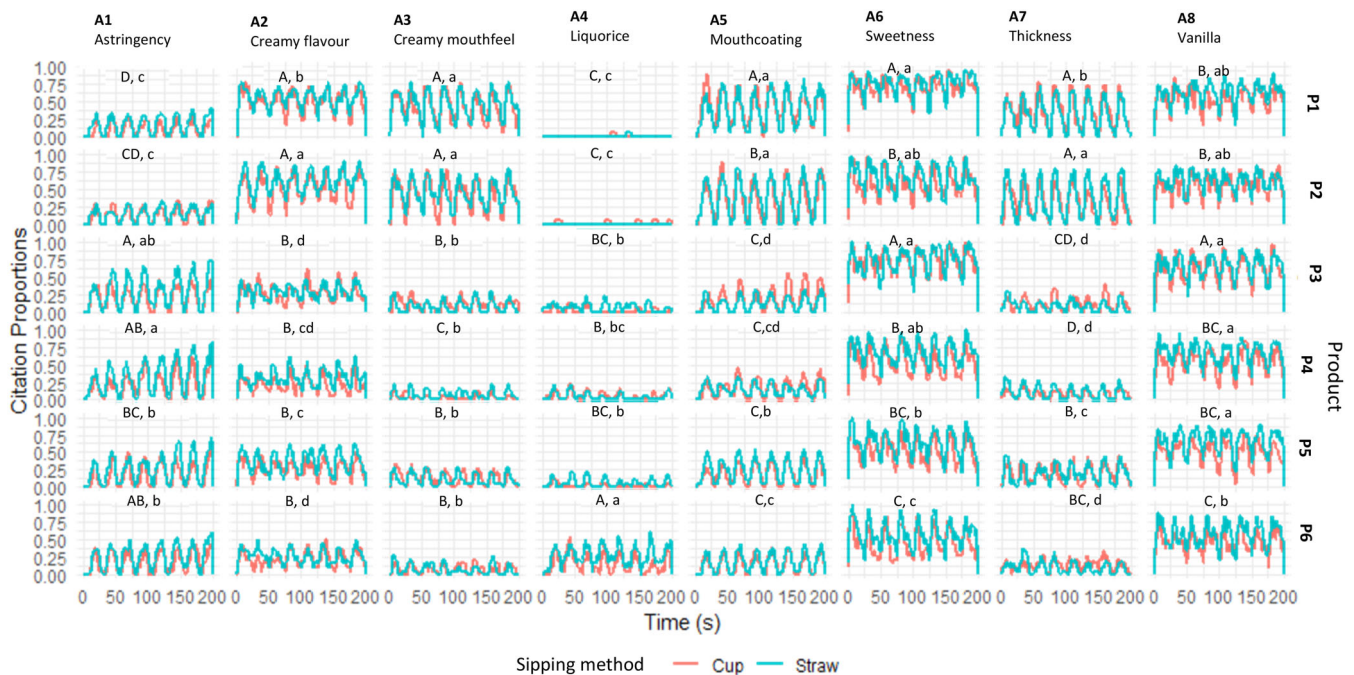


FIGURE 3 TCATA curves for sensory attributes (A1–A8 in columns) of milkshakes (P1–P6 in rows) by cup and straw sipping across eight sips. “ABCD” (Citation proportions from cup) and “abcd” (citation proportions through straw) different letter codes indicate significant attribute difference between products (Holm’s, $p < .01$). Products: P1 (HFHSLT), P2 (HFLSLT), P3 (LFHSLT), P4 (LFLSLT), P5 (LFLSHT), and P6 (LFLSSHT)

magnitude in citation increments from 3 to 7 s when sipped from a cup than through a straw. However, the interaction was small in effect size (about a 10% citation increment) (Supplementary material 1).

3.1.2 | Sipping method and product discrimination

Generally, Analysis of Deviance (Table 5) indicated that products were discriminated more across more attributes when sipped from a cup

TABLE 4 Summary of deviances and associated *p* values from a GLM three-factor Analysis of Deviance for citation proportions of sensory attributes on selected time slices for pooled sipping methods data at the first sip

	Sweetness		Vanilla		Creamy flavor		Creamy mouthfeel		Thickness		Mouthcoating		Astringency		Liquorice	
	Deviance	<i>p</i>	Deviance	<i>p</i>	Deviance	<i>p</i>	Deviance	<i>p</i>	Deviance	<i>p</i>	Deviance	<i>p</i>	Deviance	<i>p</i>	Deviance	<i>p</i>
<i>Within-sip</i> (Df = 4)	95.447	<.001	34.077	<.001	26.974	<.001	23.872	<.001	64.775	<.001	204.566	<.001	186.853	<.001	48.034	<.001
<i>Product</i> (Ddf = 5)	9.749	.083	5.743	.332	88.839	<.001	201.849	<.001	90.057	<.001	81.827	<.001	12.170	.033	56.019	<.001
<i>SippingMethod</i> (Df = 1)	14.203	<.001	18.928	<.001	3.341	.068	0.025	.875	1.179	.277	1.068	.301	5.416	.020	5.139	.023
<i>Within-sip:Product</i>	31.369	.051	11.534	.931	16.496	.685	19.408	.495	17.699	.607	12.670	.891	12.779	.887	7.189	.996
<i>Within-sip:SippingMethod</i>	0.686	.953	2.322	.677	1.477	.831	13.628	.009	4.161	.385	1.371	.849	1.978	.740	4.039	.401
<i>Product:SippingMethod</i>	4.735	.449	3.935	.559	0.754	.980	3.912	.562	2.992	.701	9.504	.091	3.364	.644	0.334	.997
<i>Within-sip:Product:SippingMethod</i>	13.636	.848	7.132	.996	11.458	.933	18.791	.535	12.759	.887	4.840	>.999	8.383	.989	9.507	.976

Note: Bold font represents significant terms ($p < .05$).
Abbreviation: GLM, generalized linear model.

TABLE 5 Summary of deviances and associated *p* values from a GLM two-factor Analysis of Deviance for citation proportions of sensory attributes on selected time slices by sipping method at the first sip

	Sweetness		Vanilla		Creamy flavor		Creamy mouthfeel		Thickness		Mouthcoating		Astringency		Liquorice	
	Deviance	<i>p</i>	Deviance	<i>p</i>	Deviance	<i>p</i>	Deviance	<i>p</i>	Deviance	<i>p</i>	Deviance	<i>p</i>	Deviance	<i>p</i>	Deviance	<i>p</i>
<i>Within-sip</i> (Df = 4)	57.761	<.001	21.507	<.001	12.350	.015	18.106	.001	22.346	<.001	100.229	<.001	85.148	<.001	28.173	<.001
<i>SippingMethod</i>	39.443	<.001	15.458	.004	16.146	.003	16.999	.002	46.102	<.001	105.832	<.001	104.361	<.001	24.210	<.001
<i>Product</i> (Df = 5)	12.620	.027	1.829	.872	44.482	<.001	99.349	<.001	50.924	<.001	63.784	<.001	11.608	.041	20.271	.001
<i>Within-sip:Product</i>	1.757	.882	7.829	.166	45.528	<.001	108.687	<.001	42.827	<.001	28.196	<.001	3.875	.568	36.820	<.001
<i>Within-sip:SippingMethod</i>	19.598	.483	7.060	.996	11.447	.934	10.769	.952	19.119	.514	6.020	.999	15.422	.752	8.365	.989
<i>Product:SippingMethod</i>	25.670	.177	11.744	.925	16.394	.692	27.553	.120	11.295	.938	10.984	.947	6.002	.999	7.899	.993

Note: Bold font represents significant terms ($p < .05$).
Abbreviations: C, sipping from cup data; GLM, generalized linear model; S, sipping through straw data.

TABLE 6 Summary of deviances and associated p values from a GLM four-factor Analysis of Deviance for citation proportions of sensory attributes on selected time slices for pooled sipping methods data across eight sips

	Sweetness		Vanilla		Creamy flavor		Creamy mouthfeel		Thickness		Mouthcoating		Astringency		Liquorice	
	Deviance	p	Deviance	p	Deviance	p	Deviance	p	Deviance	p	Deviance	p	Deviance	p	Deviance	p
Within-sip (Df = 4)	381.14	<.001	395.09	<.001	280.59	<.001	324.9	<.001	587.197	<.001	695.53	<.001	550.37	<.001	84.289	<.001
Sip (Df = 7)	29.033	<.001	12.731	.079	11.613	.114	15.854	.026	7.217	.407	6.915	.438	20.325	.005	14.763	.039
Product (Df = 5)	240.84	<.001	51.681	<.001	550.85	<.001	1.554.2	<.001	709.905	<.001	552.01	<.001	154.91	<.001	607.54	<.001
SippingMethod (Df = 1)	65.563	<.001	95.675	<.001	42.581	<.001	5.857	.016	0.066	.797	0.147	.701	71.668	<.001	44.448	<.001
Within-sip: Sip	535.55	<.001	224.48	<.001	113.78	<.001	211.35	<.001	282.811	<.001	483.7	<.001	614.38	<.001	70.854	<.001
Within-sip:Product	30.192	.067	24.257	.231	51.97	<.001	8.405	.989	47.509	<.001	48.8	<.001	13.522	.854	35.147	.019
Sip:Product	27.021	.831	15.905	.998	15.705	.998	21.163	.968	17.826	.993	22.607	.948	10.702	>.999	45.307	.114
Within-sip:Sip:Product	122.93	.847	69.49	>.999	111.7	.962	0	>.999	100.815	.997	0	>.999	0	>.999	0	>.999
Within-sip:SippingMethod	32.524	<.001	3.559	.469	5.206	.267	0	>.999	0	>.999	0	>.999	0	>.999	17.733	<.001
Sip:SippingMethod	8.934	.257	3.391	.847	3.437	.842	125.248	<.001	37,341.2	<.001	14,562	<.001	4,181.1	<.001	0	>.999
Within-sip:Sip:SippingMethod	21.985	.782	11.359	.998	10.331	.999	0	>.999	0	>.999	3,748.5	<.001	0	>.999	8,506.3	<.001
Product:SippingMethod	12.695	.026	17,096	.004	11.854	.037	2,616.2	<.001	0	>.999	16,292	>	3,748.5	<.001	0	>.999
Within-sip:Product:SippingMethod	16.206	.704	12.02	.915	17.541	.618	0	>.999	151,063	<.001	3,316	<.001	0	>.999	0	>.999
Sip:Product:SippingMethod	17.554	.994	21.768	.961	17.977	.992	0	>.999	0	>.999	0	>.999	11,390	<.001	0	>.999
Within-sip:Sip:Product:SippingMethod	0	>.999	68,288	>.999	58,009	>.999	0	>.999	0	>.999	4,469.4	<.001	0	>.999	720.87	<.001

Note: Bold font represents significant terms ($p < .05$).
Abbreviation: GLM, generalized linear model.

TABLE 7 Summary of deviances and associated p values from a GLM three-factor Analysis of Deviance for citation proportions of sensory attributes on selected time slices by sipping method across eight sips

	Sweetness		Vanilla		Creamy flavor		Creamy mouthfeel		Thickness		Mouthcoating		Astringency		Liquorice		
	Deviance	p	Deviance	p	Deviance	p	Deviance	p	Deviance	p	Deviance	p	Deviance	p	Deviance	p	
<i>Within-sip</i> (Df = 4)	C	272.42	<.001	180.93	<.001	184.75	<.001	222.65	<.001	286.39	<.001	271.49	<.001	208.08	<.001	36.61	<.001
	S	318.29	<.001	252.84	<.001	162.96	<.001	202.46	<.001	371.73	<.001	291.76	<.001	333.28	<.001	38.113	<.001
<i>Sip</i> (Df = 7)	C	7.855	.346	5.757	.568	2.841	.899	13.417	.063	2.238	.945	10.238	.176	29.114	<.001	9.858	.197
	S	17.684	.013	3.793	.803	4.09	.769	3.359	.85	8.661	.278	5.374	.614	55.287	<.001	3.882	.793
<i>Product</i> (Df = 5)	C	151.32	<.001	34.868	<.001	249.92	<.001	706.35	<.001	307.74	<.001	275.73	<.001	56.533	<.001	211.31	<.001
	S	63.61	<.001	14.634	.012	265.7	<.001	781.55	<.001	379.62	<.001	238.03	<.001	109.2	<.001	440.99	<.001
<i>Within-sip: Sip</i>	C	228.9	<.001	199.57	<.001	118.52	<.001	114.5	<.001	143.03	<.001	306.68	<.001	269.62	<.001	59.857	<.001
	S	264.42	<.001	158	<.001	102.36	<.001	134.46	<.001	146.38	<.001	279.08	<.001	361.65	<.001	50.796	.005
<i>Within-sip: Product</i>	C	30.586	.061	22.645	.307	17.597	.614	13.258	.866	33.206	.032	60.921	<.001	14.069	.827	28.096	.107
	S	11.982	.917	27.704	.117	27.569	.12	23.939	.245	44.468	.001	30.115	.068	16.284	.699	15.821	.728
<i>Sip:Product</i>	C	25.53	.879	23.402	.933	19.554	.984	29.756	.719	24.068	.918	28.216	.785	33.968	.469	42.86	.17
	S	19.347	.985	17.314	.995	13.503	>.999	21.922	.958	21.294	.967	24.524	.907	18.429	.99	43.051	.165
<i>Within-sip:Sip:Product</i>	C	104.86	.988	88.03	>.999	76.599	>.999	0	>.999	0	>.999	0	>.999	0	>.999	0	>.999
	S	102.21	.993	78.102	>.999	71.328	>.999	0	>.999	0	>.999	0	>.999	0	>.999	0	>.999

Note: Bold font represents significant terms ($p < .05$).

Abbreviations: C, sipping from cup data; GLM, generalized linear model; S, sipping through straw data.

than through a straw (Figure 2). For example, from the cup, products were significantly discriminated to some degree by all attributes, except vanilla. Through a straw, products were not significantly discriminated by sweetness and astringency, or vanilla (Figure 2, A8, A6, A1).

3.2 | Effect of sipping method on multiple sips data

3.2.1 | Sipping method and attribute citation

Similar to sip 1, Analysis of Deviance revealed significantly higher citations for all attributes except thickness and mouthcoating across multiple sips when sipped through a straw (Table 6 and Figure 3). Significant *sipping method:product* interactions were identified for sweetness, vanilla, creamy flavor, creamy mouthfeel, mouthcoating and astringency (Table 6). However, the effect sizes of the interactions were generally less than 10%. For example, sipping from a straw still led to increased sweetness citations regardless of the minimal effect of the *product:sipping method* interaction caused mainly by similar citations for P3 (Supplementary material 2).

Significant *sipping method:sip* interactions showed an effect of sipping method on the magnitude of citation dynamics across the sips on creamy mouthfeel, thickness, mouthcoating and astringency (Table 6 and Figure 3). Mouthcoating citations across sips for P3 and P4 were higher from a cup than through a straw (Figure 3, A5P3 and A5P4) for the later sips. Astringency of low-fat products (P3–P6) was cited increasingly over multiple sips through a straw, resulting in larger citation proportion differences sip to sip than when consumed from a cup (Figure 3, A1P3–A1P6). Analysis of Deviance also revealed a significant *sip:product:sipping method* interaction for astringency (Table 6). P5 only received higher magnitude citations for astringency through a straw on sips 6 to 8 (Figure 3, A1P5) however no clear citation differences across sips based on sipping method were noted for P1 and P2 (Figure 3, A1P1 and A1P2).

3.2.2 | Effect of sipping method on product discrimination across multiple sips

Significant *product* main effects were evident for all attributes, but *sipping method* was involved in significant interactions with *product* for all attributes except thickness and liquorice (Table 6). In depth, analysis of *product* effects for each sipping method was required to determine if sipping method affected level of discrimination. Analysis of Deviance showed significant *product* effects for all attributes for each sipping methods (Table 7). Post hoc testing on mean citation proportions of attributes revealed a general increment in product discrimination by both sipping methods over multiple sips compared to one sip (Figure 3). However, products were more discriminated sipped from a cup than from a straw (Figure 3). For example, sweetness of high sucrose P1 and P3 versus low sucrose P2 and P4 products within each

fat level was only differentiated when sipped from a cup (Figure 3). Similarly, higher citation proportions for vanilla differentiated P3 from the remaining products when sipped from a cup, but not through a straw (Figure 3).

The *sipping method* main effect was involved in significant interactions with temporal factors *sip* and *within-sip* (Table 6). Further investigations were performed to understand sipping method dependent impacts of these temporal factors on product profiles. Closer inspections revealed that the *sip:sipping method* interactions were, as shown in supplementary material 3 for creamy mouthfeel, very minimal, a slight drop in citation proportion (less than 5%) when sipping from the cup for sips 7 and 8. Lower citation proportions for creamy mouthfeel at sip 7 were discriminated from higher citation proportions at sip 1 from cup. In fact, sipping method did not appear to influence discrimination of mouthfeel over sips on average to any important practical level. Regardless, it is interesting that the expert panel was sensitive to slight differences in perception dynamics for some attributes across sips such as from sip 6 to 8 for creamy mouthfeel from a cup (Supplementary material 3).

Sipping method caused variations in within-sip dynamics but was only significant for sweetness and liquorice (*within-sip:sipping method* interaction, Table 6). Sweetness was cited less often sipped from a cup after-swallowing at 8 s than through a straw, but at similar rates in-mouth (Figure 4). The difference was less than 5% in citation proportion and barely impacted the level of attribute discrimination within-sip based on sipping method.

All attributes revealed significant *within-sip:sip* interactions (Table 6), emphasizing the inconsistency of within-sip experience over multiple sips. Regardless of the small size effects, attribute citation proportions were generally most different across sips at 7 s (just before swallowing at 8 s) and showed decreasing citation proportions across sips (for example sweetness: Figure 5). Exceptionally, mouthcoating and astringency were better discriminated at 3 s and showed increasing citation proportions across sips in-mouth at both 3 s and 7 s (astringency for example in Figure 6).

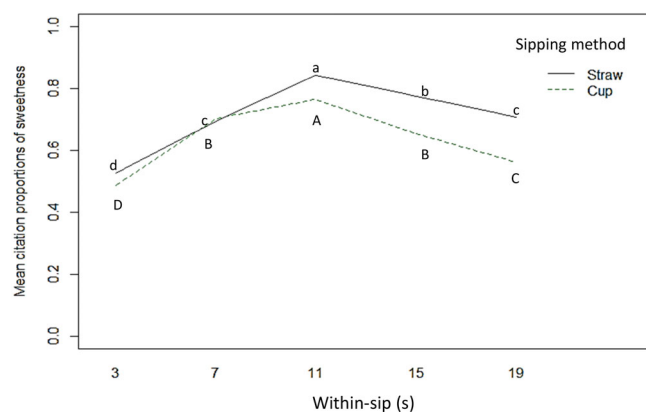


FIGURE 4 Interaction plot of *sipping method:within-sip* for sweetness. Citation proportions “ABCD” from cup and ‘abcd’ through straw with different letters are significantly different (*Holms*, $p < .01$)

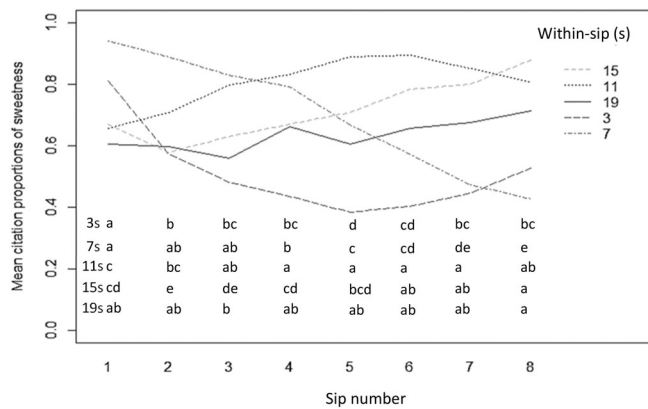


FIGURE 5 Interaction plot of *within-sip:sip* for sweetness. Citation proportions “abcde” with different letters in a row for each *within-sip* time point are significantly different across sips (Holms, $p < .01$)

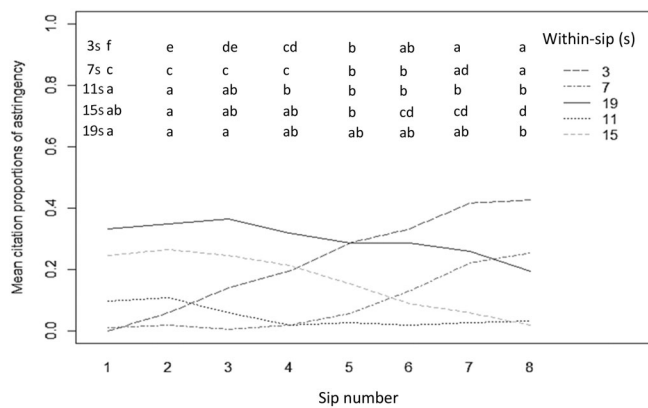


FIGURE 6 Interaction plot of *within-sip:sip* for astringency. Citation proportions “abcdef” with different letters in a row for each *within-sip* time point are significantly different across sips (Holms, $p < .01$)

Variation in the *within-sip* experience across sips was different from a cup versus through a straw (*within-sip:sip:sipping method* 3-way interaction) for mouthcoating and liquorice (Table 6) but the interactions only revealed small or barely noticeable effect sizes across sipping methods (for example for mouthcoating in Figure 7). This indicated that, depending on the sipping method in general, *within-sip* dynamic experience did not change markedly for each additional sip evaluated.

Significant *product:within-sip* interactions for creamy flavor, thickness, mouthcoating, and liquorice (Table 6) indicated that *within-sip* dynamics for these attribute citations were product specific. To further clarify this interaction, data from each sipping method was looked at separately. Analysis of Deviance on separate sipping method data showed significant *product:within-sip* interactions on thickness and mouthcoating (Table 7). For example, for mouthcoating sipping from a cup in particular drove the interaction effect observed across products, that is, increased discrimination in mouthcoating between products after-swallowing at 19 s (Figure 8).

4 | DISCUSSION

This study aimed to investigate the effects of cup versus straw sipping on TCATA sensory profiles and discrimination of vanilla milkshake on single versus multiple sips.

4.1 | Effects of sipping method based on one sip data

The results revealed impacts of sipping method on perception of the same milkshake stimulus. Flavor release varies depending on physical and physiological parameters in-mouth and in the oropharynx (Selway & Stokes, 2014). These parameters alter the fundamentals of mass transfer (i.e., diffusion and convective surface transfer) of aroma compounds at the food-air interface and taste compounds at the food-saliva interface (Salles et al., 2010). Further, physical changes in drinking behavior such as sip time, flow rate (Lin et al., 2013), pressure, vibration and auditory cues (Hashimoto et al., 2008) have been reported to impact flavor and texture perceptions. For example, bitterness of coffee was perceived more from 5 mm diameter straw than from 7.5 mm (Akiyama et al., 2012). In the present study, cup versus straw sipping would have altered the fundamental mass transfer of flavor and taste compounds resulting in higher citations of attributes when sipped through a straw. Additionally, the difference in flow rate, pressure, vibration and auditory cues through the straw (Hashimoto et al., 2008) perhaps caused panelists to cite attributes generally more often. In comparison, using a cup with product delivering to a wider area of the mouth and hence more mass transfer of stimulus, panelists would have focused more on attribute differences across products and reported higher citation differences and product differentiations from the cup. As found in mouthcoating, these differences in citations and product differentiations from cup would have further varied across attributes as well as product formulation. In fact, different levels of product discrimination, even at a single sip evaluation, would be expected where a particular sipping method is chosen. This implies that during product development, or in consumer studies, tasting protocols for sensory evaluations should be adjusted to reflect the format/s in which the product is to be consumed for example, using a cup, glass, a bottle or through a straw. Moreover, impacts of sipping method could also be a result of physicochemical interactions within the product, however this such an investigation was out of scope for this experiment.

4.2 | Effect of sipping method based on multiple sip data

A key objective of this study was to investigate if sensory perception from whole product serving of milkshakes across multiple sips differs in comparison to traditional single sip evaluations. Multiple sip data revealed attribute differences between the products that were not evident from single sip data. Interestingly, attributes were generally cited more often when sipped through a straw but discriminated more when sipped from a cup. These findings may indicate that the delivery

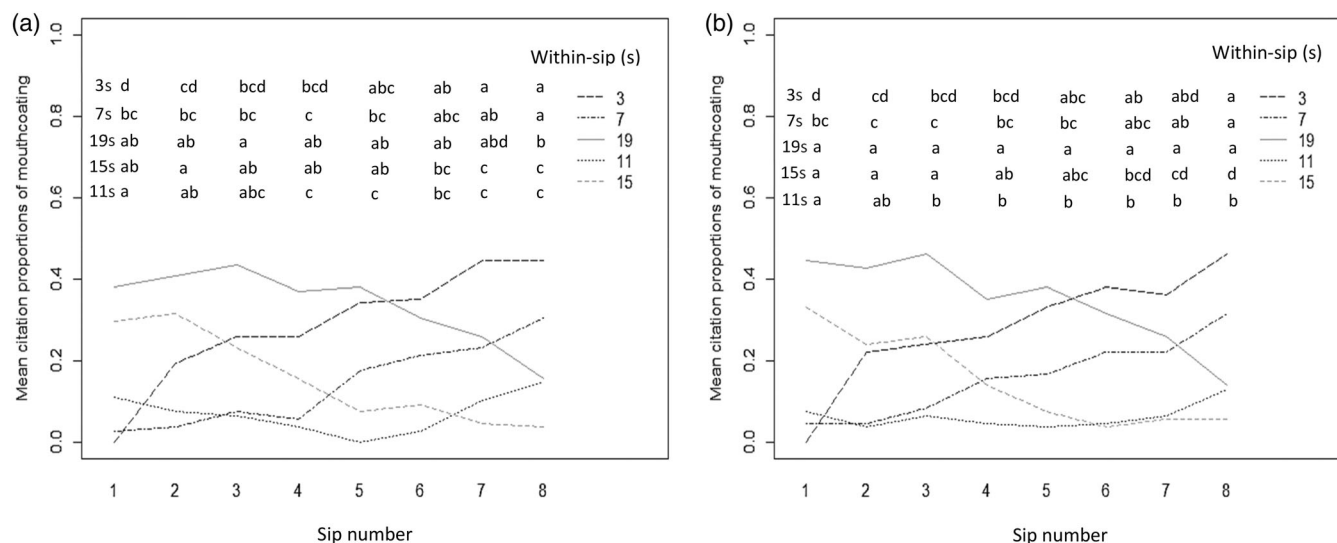


FIGURE 7 Interaction plots of *within-sip:sip* for mouthcoating (a) from cup and (b) through straw. Citation proportions “abcd” with different letters in a row for each *within-sip* time point are significantly different across sips (Holms, $p < .01$)

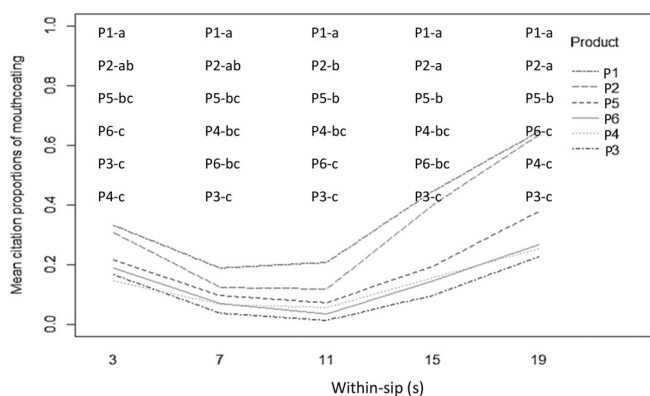


FIGURE 8 Interaction plot of *product:within-sip* for mouthcoating from cup. “abc” Products with different letters in a column for each *within-sip* time point are significantly different (Holms, $p < .01$). Products: P1 (HFHSLT), P2 (HFLSLT), P3 (LFHSLT), P4 (LFLSLT), P5 (LFLSHT) and P6 (LFLSHT)

of milkshake to a smaller and/or different area of the mouth through a straw results in attributes being more noticeable. Further, wider spread delivery of milkshake from a cup to the mouth would cover more receptors enabling better opportunity for product discrimination. However, to date, this is the first evidence to the authors' knowledge of the impact of different sipping methods on sensory perceptions.

Sipping from a cup across multiple sips discriminated more products on sweetness and vanilla. As the same amount of vanilla was added into each product formulation, increased discrimination of products for vanilla was probably an indication of perceptual interactions where increasing sweetness enhanced the vanilla perception across multiple sip evaluation (Bertelsen et al., 2021; Sikorski, Pokorny, & Damodaran, 2007). In comparison, products were

discriminated into four groups when sipped through a straw for creamy flavor as opposed to only two from sipped from a cup. This higher discrimination was likely caused by buildup of differences in mass transfer and hence higher flavor release from the straw (Hashimoto et al., 2008; Lin et al., 2013) than from a cup over multiple sips. Mouthcoating of high-fat products was more differentiated during cup sipping, and low-fat products sipping through a straw. de Wijk, Kapper, Borsboom, and Prinz (2009) showed that mouthfeel of semi-solid desserts was dependent on product composition and oral movement before swallowing affecting the coating created in oral cavity. However, in the current study, differences in oral behavior from cup versus straw sipping, and subsequent differences in oral coating and mouthfeel across cup versus straw sipping were potentially downsized by perceptual interactions of varying fat content on mouthfeel perception for the high fat versus low-fat milkshakes from a cup versus through a straw. Perceptual interactions of varying fat contents across milkshakes were not captured until sip 6 or 7, indicating a risk of losing detailed understanding of actual consumer product experience if the products were evaluated only on one sip. Differentiation of products on liquorice flavor was not impacted by sipping method but as it was only perceived in P6 (Figure 2) this was not unexpected.

Impacts of sipping method on within-sip perceptual variations were also considered. It was interesting to note when sipped from a cup, products displayed higher magnitude in the increase of citations in mouth from 3 to 7 s and is likely a consequence of increased product spread across oral cavity than when sipped through a straw. The within-sip difference in attribute citations across sipping methods increased after swallowing. As noted earlier, the physical (Hashimoto et al., 2008; Lin et al., 2013) and physiological (Selway & Stokes, 2014) changes in drinking behavior may explain the higher citation proportions observed for attribute perception through the straw, and the increased difference of citations across sipping methods after-swallowing with more tastants reaching taste receptors

(Salles et al., 2010). This within-sip citation difference across the two sipping methods showed an overall reduction over multiple sips. Increasing tastants concentration over multiple sips may have led to adaptation (Bartoshuk, Duffy, Hayes, Moskowitz, & Snyder, 2006; Keast & Roper, 2007) resulting in an overall decrease of citation differences from a cup and through a straw across sips. Sweet taste receptors are located on the tongue, soft palate, and oropharyngeal areas (Breslin & Spector, 2008) and swallowing may have assisted buildup of sweet tastants in saliva over multiple sips to increasingly activate the taste receptors resulting in an increase of sweetness perception after-swallowing. Also, after-swallowing, in-mouth residues, or changes resulting in mouthcoating and astringency perceptions may undergo saliva dilution or breakdown with time (Chen & Engelen, 2012; Salles et al., 2010). Subsequent drops in mouthcoating and astringency perception could result in increased sweetness perception after swallowing.

Generally, the within-sip experience of products varied across multiple sips with small size effects, which were attribute dependent. However, multiple sip evaluations, without using palate cleanser between sips of the same product, enabled the capture of adaptation and buildup effects providing closer insights into an actual product consumption occasion that consumers might experience. Therefore, it is important to adjust product evaluation protocols with appropriate sipping methods and over multiple sips where insights into actual consumption occasions are required. However, findings varied depending on attributes and hence more research is required with different product/ beverage categories to understand the wider effects of multiple sip evaluations on cup and straw sipping experiences.

The panel discriminated *within-sip* changes over multiple sips and the TCATA technique was sensitive enough to capture these dynamic differences across sipping method. Generally expert assessors are considered more sensitive in product discrimination due to their higher sensory acuity (Everitt, 2018; Kemp, Hollowood, & Hort, 2009) and training (Lawless & Heymann, 2013) in comparison to consumers (Ares & Varela, 2017). Further, attribute training and consistency of the analytical approach of experts in product evaluation (Ares & Varela, 2017; Lawless & Heymann, 2013; Stone & Sidel, 2004) may have been reflected in smaller size effect citation differences across sipping methods in multiple sip evaluations of the milkshakes. However, consumers are not expert panelists and so it is important that future work is carried out to understand if the differences observed here relate to consumer perception across multiple sips, and is particularly relevant to product development and optimization settings.

5 | CONCLUSIONS

Sipping method influenced citation proportions and product discrimination. Generally, higher citation proportions were given when sipped through a straw. However, products were discriminated with larger size effects when sipped from a cup. Consequently, single and multiple sip TCATA temporal profiles of products and attributes are likely to be affected by sipping method selected by the panel. Moreover, sipping method-based citation differences were more evident across

further attributes and products when evaluated across multiple sips than on single sip. This increased attribute and product discrimination emphasizes the importance of multiple sip evaluations when wanting to represent perception on the whole product consumption experience to capture actual consumer product experience. Nevertheless, these findings cannot yet be generalized as they are product and attribute specific and further studies with different product matrices and different sensory characteristics will be required. Sipping method order was not balanced across sessions in a compromise to streamline logistics during a session and could be noted as a limitation of this study. The size effects of sipping method interactions were small, but it was interesting that the panel was sensitive enough to capture such marginal differences. A key question is whether insights from an expert panel using multiple sips TCATA is similar to what is perceived by consumers and, although not covered in this study, it should be considered for future studies.

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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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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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