Food Quality and Preference 54 (2016) 160–172

Contents lists available at ScienceDirect

Food Quality and Preference

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

Comparison of two TCATA variants for dynamic sensory characterization of food products

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ARTICLE INFO

Article history:
Received 3 March 2016
Received in revised form 4 July 2016
Accepted 12 July 2016
Available online 12 July 2016

Keywords:
Temporal methods
Sensory characterization
Check-all-that-apply questions
CATA
Trained assessors
Consumers
TCATA Fading

ABSTRACT

Temporal Check-All-That-Apply (TCATA) has been recently introduced as a method for temporal sensory product characterization. This method requires assessors to select all the terms they consider applicable at each moment of the evaluation, and to de-select terms when they are no longer applicable. In the present work a variant of TCATA, TCATA Fading, is presented and compared to TCATA. In TCATA Fading selected terms gradually and automatically become unselected over a predefined period of time. Eight studies were conducted with different product categories in three different countries. In Studies 1–3, TCATA and TCATA Fading were compared with trained assessors using within-subject experimental designs on the same set of products. In Studies 4–6, TCATA and TCATA Fading were compared with consumers following between-subject experimental designs. Comparison was performed in terms of citation proportion of the terms, significant differences among samples detected, dynamic sample profiles, and task perceptions. Across the eight studies, results suggested that automatic de-selection of attributes in a TCATA task can improve discrimination and provide a more accurate description of the dynamics of sensory characteristics of products than asking consumers to de-select attributes when they are no longer applicable. The present research represents a first attempt at implementing and evaluating TCATA Fading, and suggests that it is a useful variant of the TCATA method. Many avenues for methodological refinement are identified.

1. Introduction

Understanding how the sensory characteristics of food products change during consumption has been the focus of extensive research in sensory science (Lawless & Heymann, 2010). Several temporal sensory methods have been developed for dynamic sensory characterization (Cadena, Vidal, Ares, & Varela, 2014). Traditionally, temporal measurements have been based on continuous measurement of the intensity of one or a few sensory attributes over a period of time, using different methodologies such as time-intensity, multi-attribute time intensity or sequential profiling (Kuesten, Bi, & Feng, 2013; Larson-Powers & Pangborn, 1978; Methven et al., 2010).

Temporal methods that focus on the description of the sensory characteristics of products over time (as opposed to the temporal change in intensity of a few selected attributes) have also become popular, mainly due to the development of Temporal Dominance of Sensations (TDS; Pineau, Cordelle, & Schlich, 2003). TDS is a multi-attribute methodology in which assessors are presented with a list of terms and are asked to determine the sensation that captures their attention at each moment of the evaluation (Pineau et al., 2009). This methodology has been applied to a wide range of products of different complexity (Di Monaco, Su, Masi, & Cavella, 2014).

More recently, Castura, Antúnez, Giménez, and Ares (2016) introduced another multi-attribute temporal method, Temporal Check-All-That-Apply (TCATA), which is an extension of Check-All-That-Apply (CATA) questions. In a TCATA task assessors are presented with a list of terms and are asked to select all that apply to describe the sensations they perceive at each moment of the evaluation. They can check all the attributes that they perceive at

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http://dx.doi.org/10.1016/j.foodqual.2016.07.006
0950-3293/

the same time and they have to uncheck attributes when they are no longer applicable. This methodology provides different information than TDS, as it is not based on the concept of dominance. In TCATA, attributes are selected when they are applicable to describe the sensations perceived at each moment of the evaluation and not when they catch assessors' attention. This fundamental difference enables TCATA to provide a more detailed description of the dynamic sensory profile of products during consumption than TDS (Ares et al., 2015). TCATA can be used with trained and untrained assessors for dynamic sensory characterization of food products and it has already been applied to products of different complexity, including orange juice, strawberry yogurt, French bread, chocolate-flavoured milk, cheese, salami and mussels, as well as cosmetic emulsions (Ares et al., 2015; Boinbaser, Parente, Castura, & Ares, 2015; Castura et al., 2016; Oliveira et al., 2015). In consumer studies, self-reported task perceptions indicate that participants perceive TCATA variants as easy and not tedious (Ares et al., 2015). However, further research is needed to further refine the TCATA method and develop guidelines for best practice.

One of the possible modifications is to make TCATA term selections ephemeral in nature. Theoretically, selection of terms that apply and un-selection of terms which no longer apply should be given equal weight when performing a TCATA task. This idea may, however, not accurately capture how assessors approach the task. Tentatively, they may be so focused on the task of continuously selecting terms that describe a focal sample that their attention is more directed to doing so than to un-selecting terms which no longer apply. Making term selection transient, by a process of automatic fading whereby selected terms gradually become unselected over a predefined short duration, could overcome this problem. Inspired by a recent study with TDS where the selection of the dominant attribute fade to a deselected state within a few seconds (Thomas, Visalli, Cordelle, & Schlich, 2015), a variant of TCATA (hereafter called TCATA Fading) is presented in this research and compared to TCATA for dynamic sensory characterization of food products with trained assessors and consumers. The comparison considers citation proportion of the terms, significant differences detected, dynamic sample profiles, and task perceptions.

2. Materials and methods

The present work comprised eight studies, summarised in Table 1. Different product categories were included: bread, salami, cheese, milk desserts, chocolate, and marinated mussels. In Studies 1–3 (where assessors were trained panellists) TCATA and TCATA Fading were compared using a within-subjects experimental design where trained panellists evaluated samples using both TCATA variants. In Studies 4–8 the methodological variants were compared using a between-subjects experimental design, in which consumers performed either the TCATA or the TCATA Fading task. Studies 1 and 4 were conducted in Montevideo (Uruguay), Studies 2 and 3 were performed in Buenos Aires (Argentina), and Studies 5–8 took place in Auckland (New Zealand).

2.1. Samples

In Study 1, samples corresponded to four types of bread prepared with different salt concentrations and ingredients (sodium chloride at 1.8% or 2.0%, or 2.53% of a 50:50 mixture of sodium chloride and potassium chloride) and stored for different lengths of time (1–3 days). Samples in Studies 2–3 and 5–8 were commercially available products from different brands. The salami samples in Study 2 corresponded to different brands of coarsely ground salami. In Study 3 commercial samples of Pategrás cheese, a typical semi-hard cheese from Argentina, was used. Milk desserts (Study 4) were formulated by a local producer with different sugar and flavouring concentrations. Mint flavoured dark chocolates (Study 5) were stored at 20 °C (±1 °C) and samples were served at the same temperature. In Study 6, the adductor muscle of the marinated mussels was removed prior to serving, and samples were prepared 20 min prior to tasting. All samples were drained for 2 min to remove excess marinade. Hard cheeses (e.g., cheddar), with varying flavour strength and textural characteristics, were used in Studies 7 and 8.

In all studies samples were presented labelled with random 3-digit codes for identification. Unless explicitly stated, products were stored under refrigeration temperatures (2–5 °C ± 1 °C), and removed from the refrigerator as needed, immediately prior to sensory evaluation. Serving sizes were adjusted to allow a single or several bites per sample (study dependent).

2.2. Participants

2.2.1. Trained panellists

In Studies 1–3 evaluations were performed with three different panels of 9–12 trained panellists (ages ranging from 24 to 60 years; percentage of female panellists ranging from 50% to 80%) (Table 1). All panellists had been selected according to the guidelines of the ISO 8586:2012 standard (ISO, 2012) and had experience with descriptive analysis of the target products. In Study 1, the panel had no prior experience with TCATA, but had previously been trained in attribute recognition and scaling of all sensory modalities relevant to the focal samples. Panellists had a minimum of 1-year experience in the evaluation of bread. Four additional training sessions, each lasting 15 min, were conducted to familiarize panellists with the TCATA and TCATA Fading tasks. In Studies 2 and 3, panellists had a minimum of 5 years of experience in the evaluation of the target products (Pategrás cheese or salami) using descriptive sensory analysis and TCATA. In this case, two training sessions, each lasting 15 min, were conducted to familiarize panellists with the TCATA Fading task.

Table 1
Overview of the studies included in this research.

Study	Product category	Number of samples	Experimental design to compare TCATA and TCATA Fading	Type of assessors	Total number of assessors (assessors who completed TCATA Fading between brackets)	Replicated assessments in data collection
1	Bread	4	Within-subjects	Trained assessors	12	3
2	Salami	4	Within-subjects	Trained assessors	9	3
3	Pategrás cheese	4	Within-subjects	Trained assessors	9	3
4	Milk desserts	5	Between-subjects	Consumers	103 (53)	1
5	Mint chocolate	4	Between-subjects	Consumers	154 (79)	1
6	Marinated mussels	3	Between-subjects	Consumers	129 (64)	1
7	Hard cheese	4	Between-subjects	Consumers	155 (79)	1
8	Hard cheese	4	Between-subjects	Consumers	130 (64)	1

2.2.2. Consumers

Studies 4–8 were each carried out with 103–155 consumers (Table 1). In Study 4, participants were recruited from the consumer database of the Sensometrics & Consumer Science group of Universidad de la República (Uruguay), based on their milk dessert consumption and willingness to take part in the study.

In Studies 5–8, participants were recruited in Auckland, New Zealand by a marketing research provider based on their consumption of the focal products, as well as their interest and availability to participate in the study. In these studies, data were collected as part of a consumer research project that included tasting of other foods/beverages. Studies 5 and 7 were carried out with the same group of participants. Studies 6 and 8 involved another group of participants.

The participants in Studies 4–8 were aged between 18 and 67 years old and the percentage of female participants ranged from 48% to 75%. The consumer samples comprised varying household compositions, income levels, and education levels, but they were not representative of the populations of the cities where the studies were conducted. It was a requirement that participants were familiar with computers and using a computer mouse. Participants gave written informed consent and were compensated for their participation.

2.3. Experimental procedure

The process of data collection was as similar as possible for the two TCATA variants. All assessors were instructed that the task required characterization of samples using a list of terms (which they reviewed prior to entering the sensory booth area). They were instructed that they should select all of the terms that applied at each moment of the evaluation of a focal sample. To commence data collection, assessors had to click a start button concurrently with taking a bite of sample and then immediately begin term selection. Data collection continued until sensory sensations from the samples ceased (or the duration of the task was reached). Assessors were instructed to swallow but precise instructions about when to swallow samples were not provided.

Differences in the experimental procedure for TCATA and TCATA Fading pertained to un-selection/re-selection of terms during the time course of sample evaluation. In TCATA, assessors were instructed to unselect attributes that were no longer relevant for a focal sample, and it was made clear that they could subsequently select that term again if it became applicable at a later time. Thus, their task was to select applicable terms and un-select non-applicable terms. In the TCATA Fading variant, term un-selection was automatic, and occurred gradually over a period of 8 s. If assessors considered a term to still be relevant after it had been automatically unselected, they should select it again and again, etc. Hence, in the TCATA Fading task assessors were focused on selecting (and re-selecting) applicable terms. Pilot work with samples from a subset of studies underpinned the decision to use 8 s as the time period over which a term gradually faded from selected to un-selected. This period of time was considered adequate by the assessors to enable them to focus on the task of selecting new attributes without paying too much attention to the task of re-selecting faded attributes that remained applicable to describe the focal sample. Fig. 1 shows an image from a TCATA Fading evaluation, where some terms are selected, some terms are un-selected, and other terms are partially faded.

In Studies 1–3, trained panellists evaluated samples using both TCATA and TCATA Fading, following a within-subjects experimental design. In each study data collection took place over six days. Assessors completed the three replicate assessments with one TCATA variant (one replicate assessment per day) before starting the replicate assessments of samples using the other TCATA variant. The order in which assessors completed the tasks was counterbalanced (i.e. a crossover design). In Studies 4–8, in accordance with a between-subjects experimental design, consumers were randomly divided into two evenly sized groups, each of which evaluated samples using either TCATA or TCATA Fading. Within-subjects designs were used with trained assessors as it was possible to schedule their attendance over multiple sessions. A within-subjects experimental design was less practical logistically than a between-subjects experimental design for the consumer tests. Furthermore, from a methodological comparison, it is useful to consider results from naïve consumers who have not attended previous sessions, and thus are not benefitting from task and product familiarization from a previous session. Each of these experimental designs have been extensively used by some of the authors to study methodological issues in CATA questions (e.g., Jaeger & Ares, 2014) and are deemed fit-for-purpose.

In all eight studies, testing took place in standard sensory booths that were designed in accordance with ISO 8589 (ISO, 2007), under artificial daylight and temperature control (20–22 °C). Samples were presented in sequential monadic presentation order according to a Williams' Latin Square design (Williams, 1949) which balanced for sample order and carry-over effects. Still mineral water was used for rinsing between samples in Studies 1, 4–8. In Studies 2 and 3 unsalted bread, slices of peeled Granny Smith apple, and water were used as palate cleansers. Palate cleansing between samples was enforced in studies with trained assessors, but optional in studies with consumers. This was in accordance with standard operating procedures for such panel types in the authors' research groups.

The duration of the task and the lists of terms were identical for TCATA and TCATA Fading. The attribute lists contained between 9 and 12 terms to account for differences in product categories and

Fig. 1. Example of TCATA Fading evaluation screen. The button colour indicates the selection status. Terms that are regarded as non-applicable to describe the focal sample at this time slice are not selected and appear in grey. A mouse hover event changes the button colour to white (see: Soft). Once selected the button colour changes to orange, then fades gradually to grey over 8 s. It is clear that Hard was selected most recently, preceded by Chocolate and Crunchy. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 2
Duration of the task and list of terms considered in the eight studies comparing two variants of TCATA.

Study	Product category	Task duration (s)	Number of terms	List of terms
1	Bread	50	10	Bitter, soft, spongy, metallic, sticky, characteristic bread flavour, off-flavour, salty, dry, smooth
2	Salami	40	11	Soft, hard, gummy, fibrous, greasy, pungent, characteristic salami flavour, spicy, off-flavour, salty, brittle
3	Pategrás cheese	45	12	Soft, sticky, bitter, sour, creamy, firm, gummy, pungent, characteristic Pategrás cheese flavour, off-flavour, salty, melting
4	Milk desserts	30	9	Thick, creamy, sweet, gummy, liquid, sweet aftertaste, vanilla flavour, off-flavour, milk flavour
5	Mint chocolate	80	10	Bitter, chocolate, cooling, crunchy, gooey, hard, melting, mint, soft, sweet
6	Marinated mussels	90	9	Chewy, firm, garlic, moist, savoury, smoky, soft, sour/acidic, sweet
7	Hard cheese	70	10	Dry, firm, mild flavour, rubbery, salty, sharp, soft, sticky, strong flavour, sweet
8	Hard cheese	70	10	Dry, firm, mild flavour, rubbery, salty, sharp, soft, sticky, strong flavour, sweet

degree of stimuli complexity. In studies involving trained panellists, terms were selected by them through evaluation of commercial samples within the product category and discussion with the panel leader. The terms had precise definitions selected by the panellists and references were used to exemplify the terms prior to the TCATA task. In studies involving consumers, terms were selected considering results of previous consumer studies and pilot work, but no explanations of terms were provided. Presentation order of the terms was balanced between assessors following a Williams' Latin square design (Williams, 1949). The terms included in each of the eight studies are shown in Table 2.

Self-reported task perception measures were obtained in Studies 4–8. Consumers indicated their agreement with two statements using 7-point Likert scales immediately after completion of the task (TCATA or TCATA Fading): i) It was easy to answer the questions about these samples; and ii) It was tedious to answer the questions about these samples. All categories of the scale were labelled, with endpoint anchors 1 = 'disagree extremely' and 7 = 'agree extremely'. These questions were identical to those used by Ares et al. (2015) to facilitate task perception comparison of methods in previous studies. Self-reported task perceptions were not obtained in studies with trained assessors as this is not commensurate with standard procedure.

For the studies involving consumer participants (Studies 4–8), differences in the distribution of age, gender, frequency consumption, and liking of the focal products were non-significant between the two TCATA variants (*p-value* higher than 0.19). Hence, it was possible to infer that differences between experimental treatments may be mainly linked to differences in study protocol, as opposed to differences in participant characteristics.

Language was appropriate for each country: Spanish for studies in Argentina and Uruguay, and English for the studies conducted in New Zealand. Data collection was carried out using *Compusense Cloud* (Compusense Inc., Guelph, Canada).

2.4. Data analysis

Analyses were performed to facilitate comparison of the two TCATA variants and pertained to citation proportion, sample discrimination, dynamic sensory profiles, and task perceptions. The procedures proposed by Castura et al. (2016) were followed and analyses were identical for TCATA and TCATA Fading. All data analyses were carried out using R version 3.2.0 (R Core Team, 2015).

The number of terms selected by each assessor for each of the samples at each moment of the evaluation (every 1 s) was calculated. Then, average citation proportion across samples and assessors for the total duration of the task was calculated. Fisher's exact test was used to compare citation proportions obtained using TCATA and TCATA Fading.

For each sample, aggregated data across all participants were represented using line plots. The citation proportion of each term was calculated as the proportion of judgments (assessors x replicates) for which it was selected for describing a sample at any given time of the evaluation (every 1 s). TCATA curves were smoothed using a spline type polynomial in the `pspline` package (Ramsey & Ripley, 2013). The maximum citation proportion for each sample was determined.

TCATA difference plots for pairs of samples were obtained in a manner analogous to TDS difference plots, i.e. by subtracting their citation proportions. A sign test was applied at each time point (every 1 s) and for each attribute to evaluate whether citation proportions for the two products were statistically significant from zero at the 5% significance level, as proposed by Meyners, Castura, and Carr (2013) for CATA data.

Self-reported perceptions of task ease/tediousness were analysed using unpaired Student t-tests (Studies 4–8 only).

3. Results

The findings are presented in four sub-sections pertaining to citation proportions, dynamic sensory profiles, sample discrimination, and task perceptions, respectively. For the sake of clarity results from studies with trained panellists are presented separately from findings from studies with consumers. In line with the aim of the research, focus was directed to a comparison of the two TCATA variants and herein the studied products were exemplars rather than being of specific interest. As expected, differences in citation proportions for TCATA terms, dynamic sensory profiles and sample discrimination were established between product categories. However, these differences are not presented/discussed in detail unless to help explain findings from the methodological comparison of the two TCATA variants.

3.1. Comparison of citation proportions

3.1.1. Results for studies conducted with trained panellists

In all three studies, results showed that average citation proportions were significantly lower in the TCATA Fading variant, in which terms were automatically un-selected. For TCATA and TCATA Fading, respectively, the average citation proportions across samples were 0.30 vs. 0.26 (S1), 0.25 vs. 0.16 (S2), and 0.17 vs. 0.15 (S3) (Table 3i). The decrease in citation proportions was study specific and could be linked to the product category and/or panel members' experience with TCATA tasks. The maximum term citation proportions for individual samples (Table 3ii) were also higher in TCATA than TCATA Fading. For example, in Study 1 (bread), the citation proportions were 0.70–0.88 vs. 0.60–0.69. At the last evaluation time (e.g., 50 s for Study 1, which was the task duration for that study) the term citation proportions (Table 3iii and iv) for TCATA Fading were lower than for TCATA. Study 2 (salami) illustrates this pattern as well. Average citation proportions in TCATA

Table 3
Summary of results pertaining to citation proportions and sample discrimination for the three studies comparing TCATA and TCATA Fading with trained panellists (Studies 1–3).

Results pertaining to	Parameter	Methodology	Study 1 (bread)	Study 2 (salami)	Study 3 (Pategrás cheese)
Citation proportions	(i) Average term citation proportion across samples (*)	TCATA	0.30 [a]	0.25 [a]	0.17 [a]
		TCATA Fading	0.26 [b]	0.16 [b]	0.15 [b]
	(ii) Maximum term citation proportion for individual samples	TCATA	0.70-0.88	0.66-0.78	0.53-0.77
		TCATA Fading	0.60-0.69	0.52-0.75	0.31-0.47
	(iii) Average term citation proportion across samples at the last evaluation time	TCATA	0.13	0.40	0.29
		TCATA Fading	0.08	0.26	0.15
	(iv) Maximum term citation proportion across samples at the last evaluation time for individual samples	TCATA	0.30-0.40	0.64-0.82	0.63-0.74
		TCATA Fading	0.20-0.42	0.49-0.57	0.31-0.47
Sample discrimination	(v) Percentage of all possible comparisons between pairs of samples that were significant throughout the task duration	TCATA	11%	16%	4%
		TCATA Fading	18%	6%	3%
	(vi) Number of terms with significant differences for pairwise comparisons between samples	TCATA	0–4	5–7	3–7
		TCATA Fading	1–8	3–6	3–7

(*) Term citations with different superscripts are significantly different according to Fisher's exact test ($p < 0.05$).

and TCATA Fading were 0.40 and 0.26, and maximum term citation proportions for individual samples were 0.64–0.82 and 0.49–0.57.

3.1.2. Results from studies conducted with consumers

When considering the four indices pertaining to citation proportions across the five studies conducted with consumers (S4–S8) the dominant pattern of results was that citation proportions were significantly lower in the TCATA Fading variant compared to regular TCATA. Table 4 shows this pattern applies for the average citation proportion across all samples (4i), the maximum citation proportion for individual samples (4ii), the average citation proportion across samples at the last evaluation time (4iii), and the maximum citation proportion across samples at the last evaluation time for individual samples (4iv). Consider Study 5 (mint chocolate) as an example. The average citation proportion across samples was 0.31 and 0.15 in TCATA and TCATA Fading, respectively. Similarly, for the maximum citation proportion for individual samples ranged from 0.81 to 0.92 in TCATA and from 0.47 to 0.60 in TCATA Fading. When these indices were calculated for the last evaluation time (iii and iv), the citation proportions were lower than when calculated across the entire evaluation period. However, the two indices showed similar findings: citation proportions were lower in TCATA Fading than in TCATA.

Only in Study 4 (milk desserts) results slightly deviated from the pattern described. Although citation proportions for TCATA Fading were lower than for TCATA, the average citation proportion across samples was higher at the last evaluation time than across all time points (Table 4iii: 0.37 vs. 0.23). The reason for this result is unclear, but could be related to the short evaluation period (30 s) whereby data collection was perhaps stopped before assessors no longer could identify sensory sensations from the samples (sensory sensations after swallowing was of limited interest in Study 4 for commercial reasons).

3.2. Dynamic sensory profiles

3.2.1. Results from studies conducted with trained panellists

For the two TCATA variants considered in this research, the curves obtained with TCATA and TCATA Fading had very similar profiles for all samples evaluated in the studies conducted with trained assessors. The terms with the highest citation proportion and the time elapsed until the maximum citation proportion were similar for both methodologies, suggesting that the dynamic sensory profiles provided similar information. Fig. 2 shows exemplar TCATA curves for the one sample in each of the three studies conducted with trained assessors.

In Study 1 (bread), for both TCATA variants, Sample 1 was characterized by a high citation proportion of the terms *spongy*, *soft*, and *smooth* at the beginning of the evaluation, and by *characteristic bread flavour* at the end of the evaluation (Fig. 2a). The main difference pertained not to the profile of the dynamic evaluation, but to

Table 4
Summary of results pertaining to citation proportions and sample discrimination for the five studies comparing TCATA and TCATA Fading with consumers (Studies 4–8).

Results pertaining to	Parameter	Methodology	Study 4 (milk desserts)	Study 5 (chocolate)	Study 6 (mussels)	Study 7 (cheese)	Study 8 (cheese)
Citation proportions	(i) Average term citation proportion across samples (*)	TCATA	0.23[a]	0.31[a]	0.32[a]	0.22[a]	0.25[a]
		TCATA Fading	0.17[b]	0.15[b]	0.13[b]	0.10[b]	0.12[b]
	(ii) Maximum term citation proportion for individual samples	TCATA	0.56–0.70	0.81–0.92	0.74–0.89	0.74–0.90	0.75–0.90
		TCATA Fading	0.38–0.49	0.47–0.60	0.49–0.62	0.42–0.66	0.49–0.72
	(iii) Average term citation proportion across samples at the last evaluation time	TCATA	0.37	0.17	0.22	0.14	0.21
		TCATA Fading	0.18	0.06	0.04	0.03	0.06
	(iv) Maximum term citation proportion across samples at the last evaluation time for individual samples	TCATA	0.52–0.70	0.39–0.55	0.30–0.56	0.26–0.37	0.42–0.49
		TCATA Fading	0.30–0.42	0.15–0.19	0.08–0.14	0.08–0.13	0.13–0.25
Sample discrimination	(v) Percentage of all possible comparisons between pairs of samples that were significant throughout the task duration	TCATA	8%	48%	25%	51%	58%
		TCATA Fading	4%	33%	20%	39%	39%
	(vi) Number of terms with significant differences for pairwise comparisons between samples	TCATA	0–5	8–10	4–6	8–10	7–10
		TCATA Fading	2–7	9–10	7–8	10	9–10

(*) Term citations for a study with different superscripts are significantly different according to Fisher's exact test ($p < 0.05$).

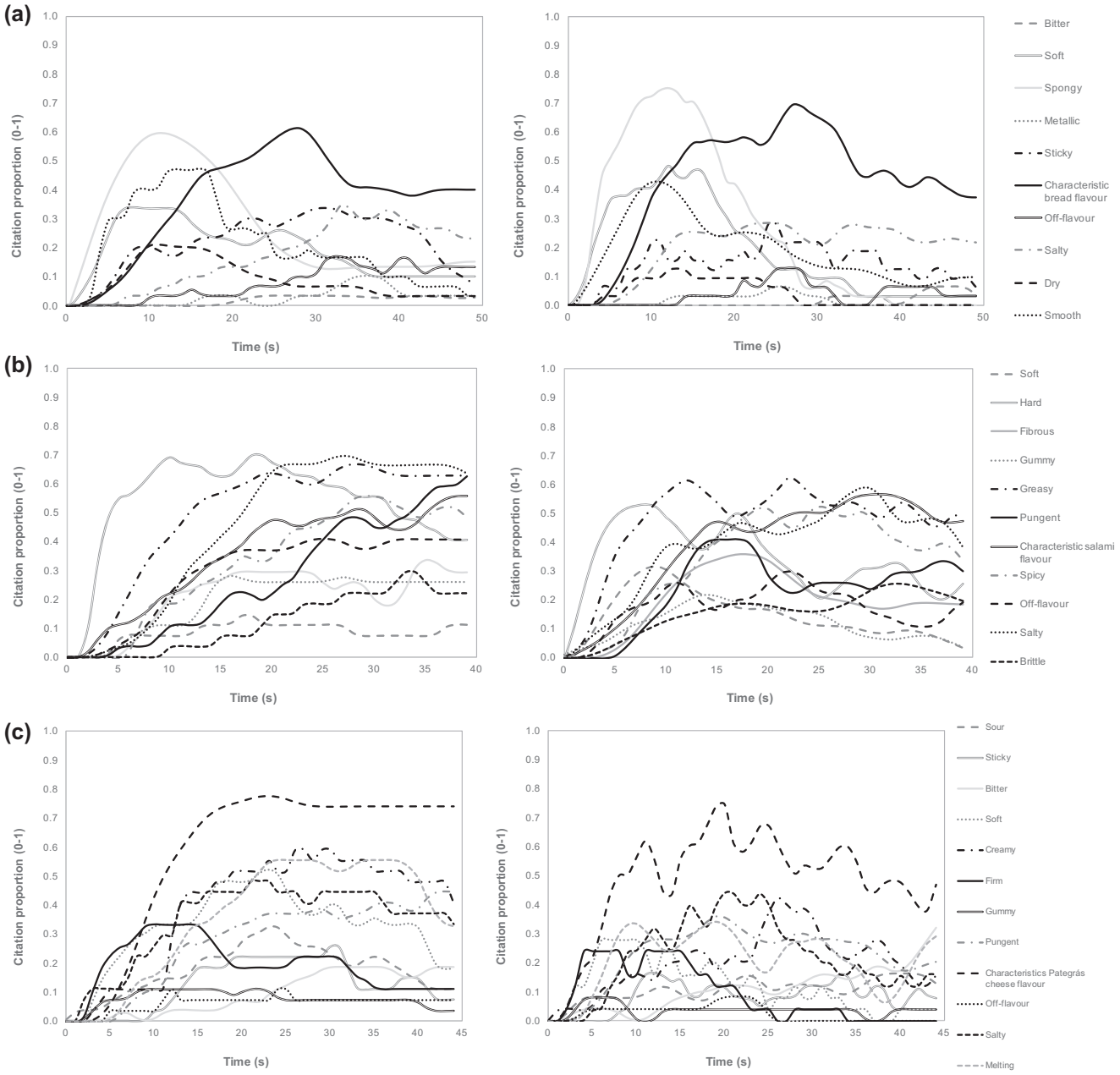

Fig. 2. Exemplar TCATA curves for the TCATA task (left) and TCATA Fading (right) obtained with trained panellists: (a) Sample 1 in Study 1 (bread), (b) Sample 3 in Study 2 (salami), and (c) Sample 3 in Study 3 (Pategrás cheese).

the citation proportion of the terms. In the TCATA Fading task the attributes *spongy* and *soft* have higher citation proportions than in the TCATA task, whereas the opposite was found for *smooth* and *sticky*. Additionally, small differences in the temporal evaluation of citation proportions were found. For example, the term *salty* reached citation proportions close to 0.30 after 10 s in the TCATA Fading task and after 30 s in the TCATA task.

According to the TCATA task, Sample 3 in Study 2 (salami) was characterized by the high citation proportion of the term *hard* during the whole evaluation period. Citation proportions of the terms *greasy*, *salty*, *pungent*, *characteristic salami flavour*, and *spicy* increased during the evaluation time, reaching values between 0.49 and 0.64 at the end of the evaluation (Fig. 2b). Similar information was obtained in the TCATA Fading task, although the attributes showed lower citation proportions. As shown in the right side of Fig. 2b, *hard* had the highest citation proportion at the beginning of the evaluation but it decreased with evaluation time, reaching 0.25 at the end of the evaluation. In contrast, citation proportion of the attributes *greasy*, *salty*, *characteristic salami flavour*, and *spicy* increased with evaluation time. These attributes showed the highest citation proportions at the end of the evaluation. The time evolution of the attribute *pungent* was captured differently in the TCATA and TCATA Fading task. In the first variant, its citation proportion increased with evaluation time, whereas in the TCATA Fading task a maximum was observed between 14 and 18 s (Fig. 2b). Similarly, citation proportion of *soft* tended to be constant in the TCATA task, whereas a maximum was observed at the beginning of the evaluation in the TCATA Fading task.

The differences between TCATA and TCATA Fading that were observed in Studies 1 and 2 were also observed in Study 3 (Pategrás cheese), as exemplified in Fig. 2c for Sample 3. The term *characteristic Pategrás cheese flavour* dominated the dynamic

profile in both TCATA variants. However, the curve for this term based on the TCATA variant reached a maximum and plateaued, whereas the curve for this term based on TCATA Fading fluctuated, likely due to automatic de-selection of the attribute, and re-selection by assessors, sometimes after a few seconds had passed. In the TCATA task the terms *creamy*, *salty*, *soft*, and *melting* showed citation proportions higher than 0.40 in the period of time elapsed between 20 and 45 s. Whereas *creamy* and *salty* plateaued in the TCATA variant, these attributes each reached a clear maximum citation rate for the evaluations performed using the TCATA Fading variant. The terms *soft* and *melting* had lower citation frequencies in the TCATA Fading task than in the TCATA variant, and were relevant for describing samples at different moments of the evaluation.

3.2.2. Results from studies conducted with consumers

Differences between TCATA and TCATA Fading in the studies involving consumers were similar to the differences between the variants that were observed in the studies conducted with trained panellists. Curves for exemplar samples in Studies 4–6 are shown in Fig. 3 but similar results were obtained for all samples in the five studies involving consumers.

In the TCATA task, the most relevant terms for describing Sample 3 in Study 4 (milk desserts) were *creamy*, *sweet*, *vanilla flavour*, *liquid*, and *sweet aftertaste.* A similar result was observed in TCATA Fading variant, despite the lower citation proportions. However, conclusions regarding the dynamics of these sensory attributes differed. Citation proportions increased with evaluation time in the TCATA variant, whereas task maximum citation proportions were

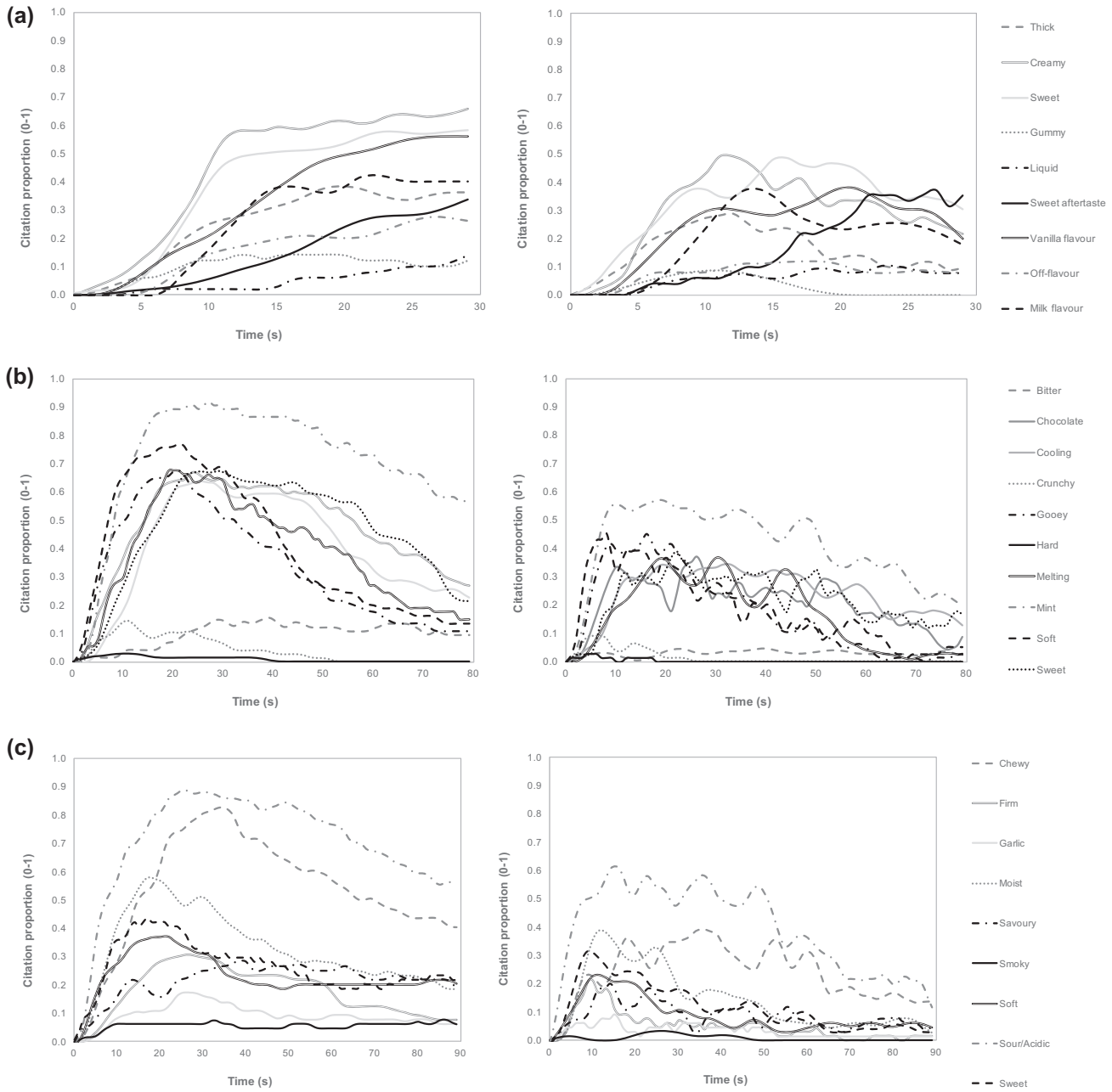

Fig. 3. Exemplar TCATA curves for the TCATA task (left) and TCATA Fading (right) curves obtained with consumers: (a) Sample 3 in Study 4 (milk desserts), (b) Sample 1 in Study 5 (mint chocolate), (c) Sample 2 in Study 6 (mussels), (d) Sample 3 in Study 7 (hard cheese), and (e) Sample 3 in Study 8 (hard cheese).

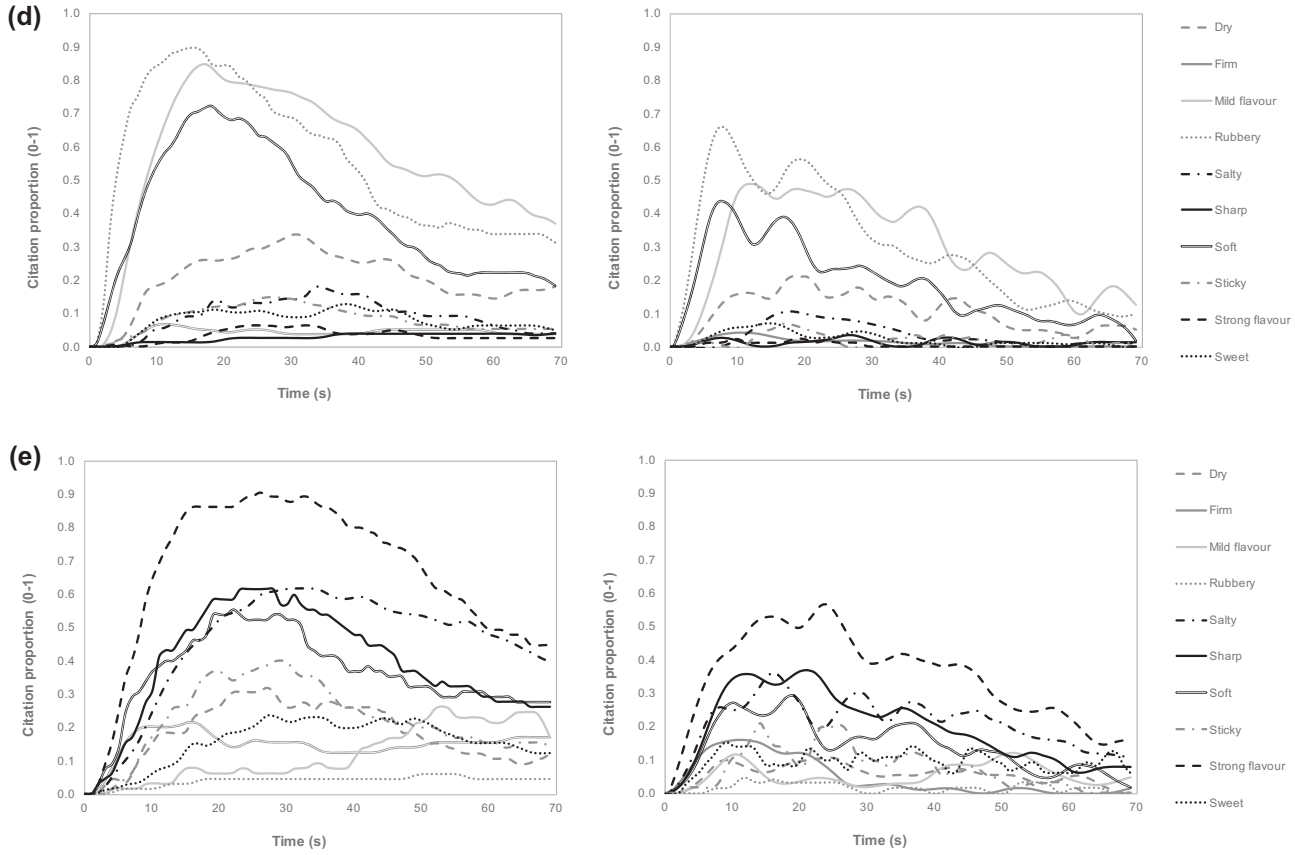

Fig. 3 (*continued*)

observed midway in the evaluation period in the TCATA Fading variant (Fig. 3a). For example, in the TCATA variant, the citation proportion of the term *creamy* increased monotonically, whereas in the TCATA Fading variant its citation proportion increased at the beginning of the evaluation, reached its maximum around 12 s, then decreased until the end of the evaluation.

In Study 5 (mint chocolate) TCATA curves were almost identical for both tasks, but citation proportions for TCATA Fading were lower, as exemplified for Sample 1 in Fig. 3b. *Mint* was the term with the highest citation proportion in both TCATA variants, whereas the terms with the lowest citation proportions were *bitter*, *hard*, and *crunchy*.

Similar results were obtained in Study 6 (marinated mussels). As shown in Fig. 3c, the term with the highest citation proportion in both TCATA and TCATA Fading was *sour/acidic*, followed by *chewy*, *moist*, and *sweet*. The main differences between the tasks were the lower citation proportions in TCATA Fading and the more gradually changing curves in TCATA.

Dynamic sensory profiles of samples in Studies 7 and 8 (hard cheese) were highly similar for TCATA and TCATA Fading. The only relevant difference between the two variants was related to the lower term citation proportions of TCATA Fading compared to TCATA. Fig. 3d and e shows exemplar curves for Sample 3 in Studies 7 and 8, respectively.

3.3. Sample discrimination

3.3.1. Results from studies conducted with trained panellists

Differences in the discriminative ability of TCATA and TCATA Fading were uncovered in the three studies conducted with trained panellists, which followed different patterns. As shown in Table 3v, the percentage of pairwise comparisons between samples that were significant during the evaluations were higher in the TCATA variant than in the TCATA Fading in Studies 2 and 3, whereas the opposite trend was found in Study 1. Besides, in Study 2 the number of attributes with significant differences for pairwise comparisons between samples (Table 3vi) was higher for TCATA than for TCATA Fading, whereas the opposite was found in Study 1. No differences were found in Study 3. Fig. 4 shows difference curves for exemplar comparisons between pairs of samples from studies involving trained panellists.

The number of pairwise differences between Samples 1 and 2 in Study 1 (bread) were highly similar for both TCATA variants. As shown in Fig. 4a, differences between samples in the attribute *dry* were identified in both tasks during most of the evaluation period. Significant differences between samples were also identified for *off-flavour, soft, spongy*, and *smooth.* The main differences between the TCATA and TCATA Fading variants were related to the duration and size of the differences between samples (Fig. 4a). Additionally, a small but significant difference in *characteristic bread flavour* was identified in the TCATA Fading variant but not in TCATA.

In Study 2 (salami), significant differences between Samples 2 and 4 were found in the attributes *off-flavour*, *greasy*, and *soft* in both TCATA variants. However, the duration of the differences between samples were longer for TCATA than for TCATA Fading (Fig. 4b). Additionally, significant differences for some terms were established for only one of the TCATA variants. As shown in Fig. 4b, significant differences between Samples 2 and 4 in *brittle* and *characteristic salami flavour* were only established in TCATA, whereas differences in *fibrous* and *hard* were only established in the TCATA Fading variant.

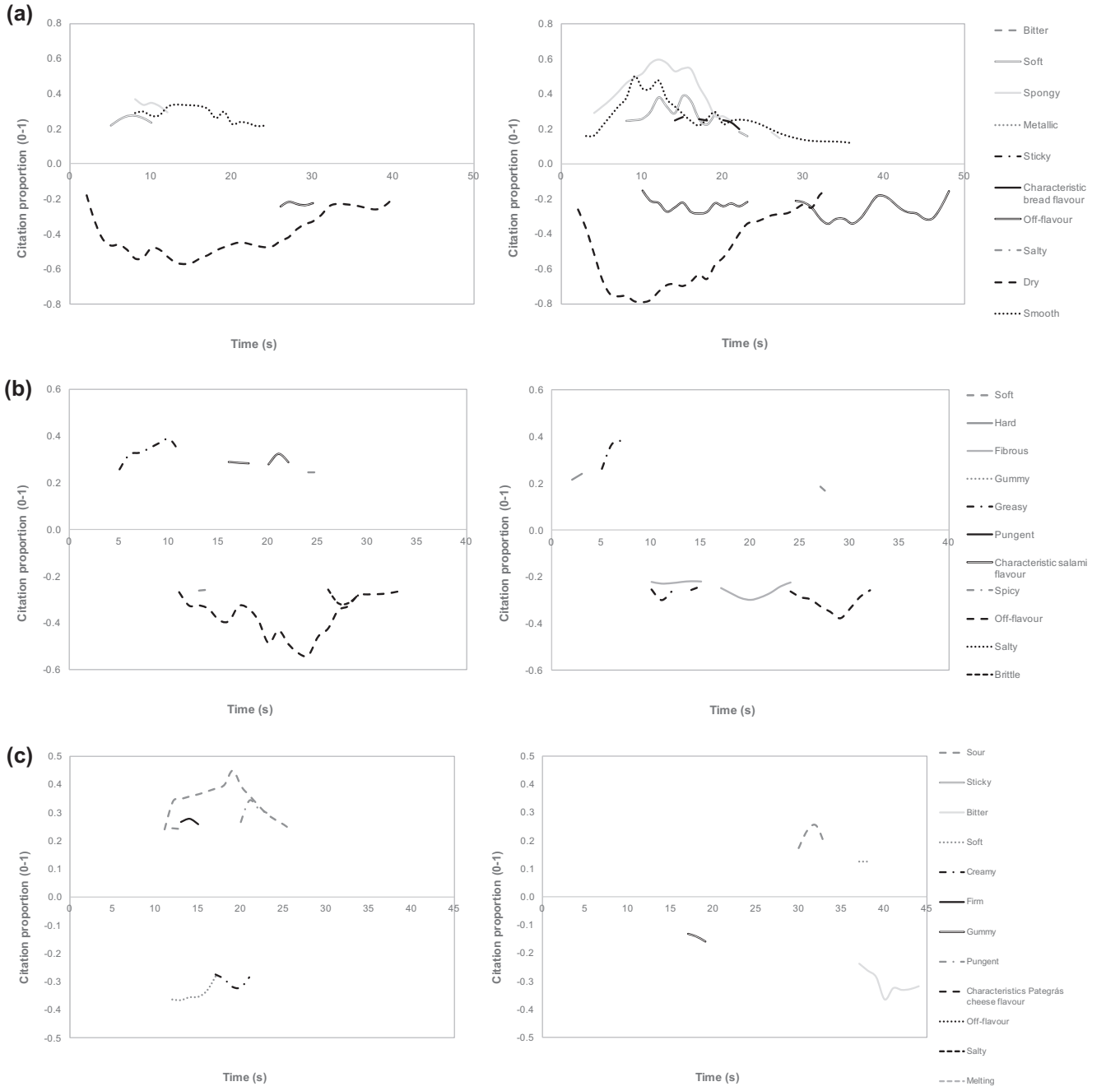

Fig. 4. Difference curves showing significant differences between exemplar pairs of samples obtained with trained panellists for TCATA (left) and TCATA Fading (right): (a) Sample 1–Sample 2 in Study 1 (bread), (b) Sample 2–Sample 4 in Study 2 (salami), and (c) Sample 1–Sample 2 in Study 3 (Pategrás cheese). Positive values for the difference indicate that the first sample received higher citation proportions than the second sample, whereas negative values indicate the opposite difference.

In Study 3 (*Pategrás* cheese) significant differences between Samples 1 and 2 were not identical for TCATA and TCATA Fading (Fig. 4c). There was agreement across the two TCATA variants regarding the existence of significant differences in *sour*, but differences regarding the duration of this significant difference were found. TCATA also identified significant differences in *creamy*, *pungent*, and *firm*, which were not detected in TCATA Fading. On the contrary, TCATA Fading identified significant differences in *gummy* and *bitter*, which were not established in TCATA. According to the TCATA task citation proportion for *soft* was lower for Sample 1 and for Sample 2 at the beginning of the evaluation, whereas the opposite difference was found at the end of the evaluation in the TCATA Fading task.

3.3.2. Results from studies conducted with consumers

Differences between the two TCATA variants regarding the ability to discriminate between samples were also found in the studies involving consumers. As shown in Table 4v, the percentage of significant pairwise comparisons between samples throughout the evaluation was higher for TCATA than for TCATA Fading. However, the opposite trend was found for the number of terms with significant differences for pairwise comparisons between samples (4vi). Differences in the conclusions regarding differences among samples are exemplified in Fig. 4 for selected pairs of samples in Studies 4–8.

In Study 4 (milk desserts), the TCATA task only identified significant differences between Samples 1 and 3 in *liquid*. These

differences were also uncovered in the TCATA Fading task, but for a shorter period of time. However, in TCATA Fading several other significant differences were identified: citation proportions of the terms *gummy*, *thick*, and *sweet aftertaste* were significantly higher for Sample 1 than for Sample 3, whereas citation proportions of the terms *off-flavour* and *milk flavour* were significantly lower (Fig. 5a).

As shown in Fig. 5b (Study 5: mint chocolate), TCATA and TCATA Fading identified the same significant differences between Samples 1 and 2 throughout the evaluation period. However, the time period during which differences between samples were significant tended to be longer for TCATA than TCATA Fading, as also evidenced by the higher percentage of significant pairwise comparisons throughout the task duration (Table 4v).

In Study 6, TCATA identified significant differences between Samples 2 and 3 for five terms, *garlic*, *soft*, *sour/acidic*, *smoky*, and *savoury* (Fig. 5c). In the TCATA Fading task similar significant differences were identified in the terms *smoky*, *sour/acidic*, and *garlic*. In TCATA Fading differences among samples were also identified in *firm*, *moist*, and *sweet*, whereas differences in *soft* and *savoury* were not significant.

Studies 7 and 8 (hard cheese) provided similar insights on the differences in discrimination between TCATA and TCATA Fading, as exemplified for one pair of samples in each study in Fig. 5d and e. As shown, the main differences between samples were identified by both TCATA variants. However, the time period during which differences were significant tended to be longer for TCATA than for TCATA Fading. Besides, TCATA Fading

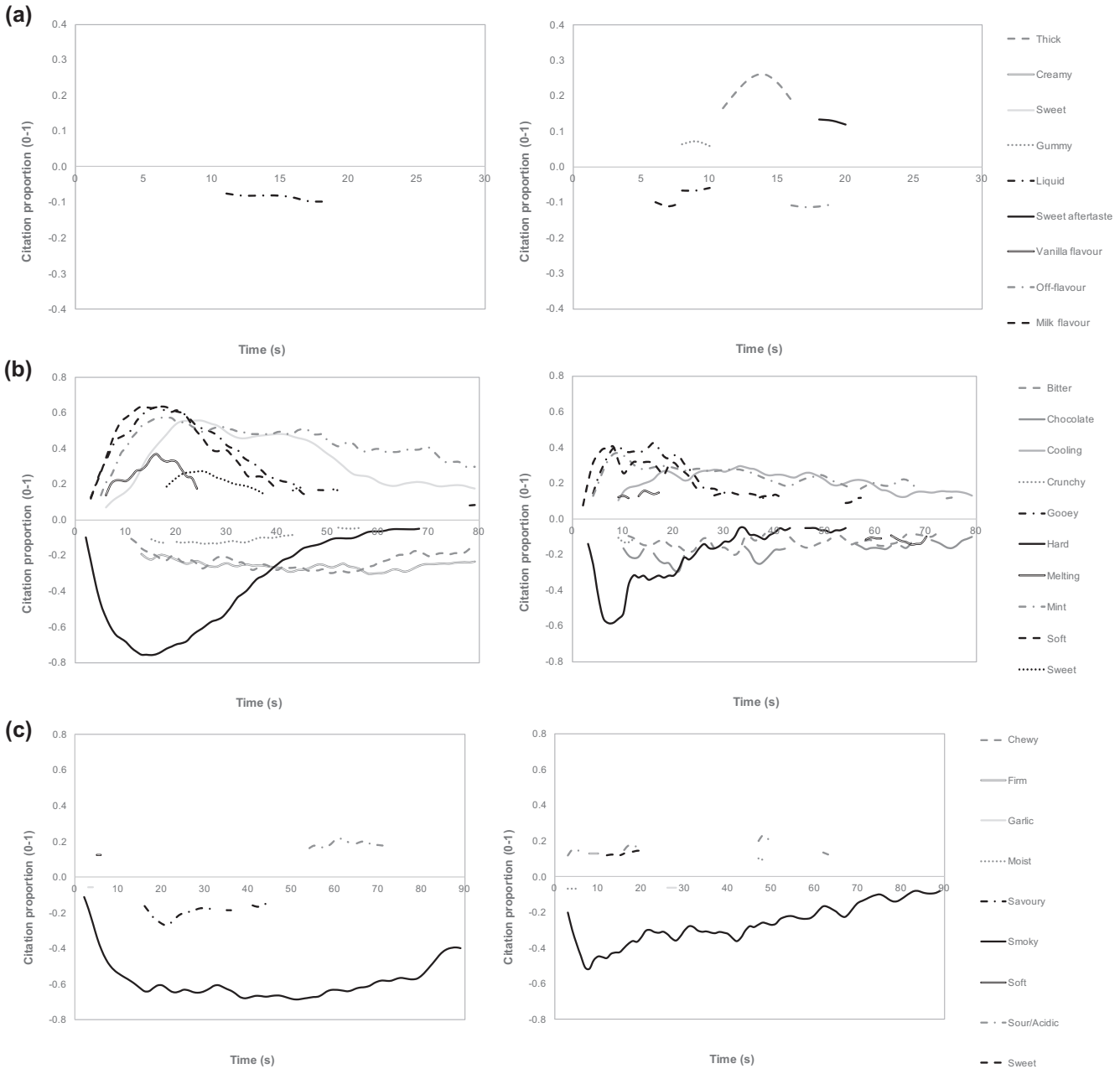

Fig. 5. Difference curves showing significant differences between exemplar pairs of samples obtained with consumers for TCATA (left) and TCATA Fading (right): (a) Sample 1–Sample 3 in Study 1 (milk desserts), (b) Sample 1-Sample 2 in Study 5 (mint chocolate), (c) Sample 2–Sample 3 in Study 6 (mussels), (d) Sample 3–Sample 4 in Study 7 (hard cheese), and (e) Sample 2–Sample 4 in Study 8 (hard cheese). Positive values for the difference indicate that the first sample received higher citation proportions than the second sample, whereas negative values indicate the opposite difference.

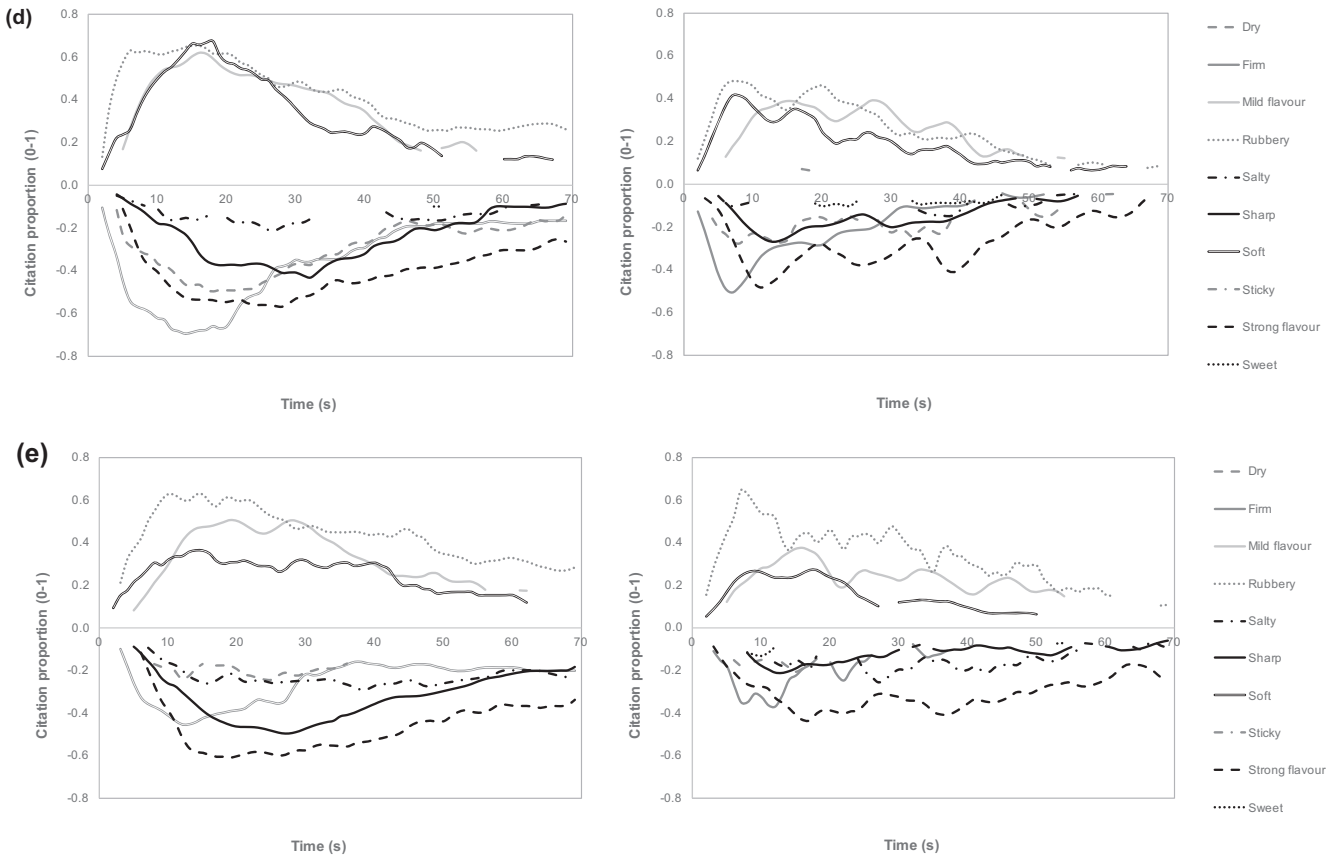

Fig. 5 (*continued*)

identified significant differences in attributes that TCATA did not capture: *sticky* for the comparison of Samples 3 and 4 in Study 7 and *sweet* for the comparison between Samples 2 and 4 in Study 8.

3.4. Self-reported task perceptions

Immediately after completing the TCATA or TCATA Fading task, consumers answered two task perception questions. Table 5 shows the means, standard deviations, and p-values from the *t*-tests comparing the two TCATA variants. In each of the four studies, the mean of the responses to the statement "It was easy to answer the questions" aligned with the verbal anchor "agree strongly" for both TCATA and TCATA Fading. In Studies 4 and 8, significant differences between the TCATA variants were not found, whereas in Studies 5 and 7 TCATA Fading was perceived to be slightly easier than TCATA, although the magnitude of the difference was small (0.3–0.4 of 7).

For the statement "It was tedious to answer the questions," the mean of the responses aligned to the verbal anchors "disagree extremely" or "disagree strongly", regardless of the TCATA variant. Significant differences between TCATA and TCATA Fading were only found in Study 5, in which TCATA Fading was perceived as slightly less tedious than TCATA (3.1 vs. 2.5).

4. Discussion

In this study TCATA Fading, a variant of the TCATA method wherein selected terms automatically become un-selected was compared to TCATA without fading (i.e., "regular" TCATA). Across eight studies involving trained panellists and consumers and a range of product categories consistent results emerged. The results are discussed below to underpin the broader question: is TCATA Fading a useful variant of the TCATA method?

Citation proportions for terms was one of the criteria used to compare the two TCATA variants and it was in this set of results

Table 5
Summary of results for the comparison of task perceptions for TCATA and TCATA Fading with consumers in Studies 4–8. Values shown are means with standard deviations between brackets. Rating scales anchored at 1 = "disagree extremely" and 7 = "agree extremely".

Statement about task perception	Methodology	Study 4 (milk desserts)	Study 5 (mint chocolate)	Study 6 (marinated mussels)	Study 7 (hard cheese)	Study 8 (hard cheese)
It was easy to answer the questions	TCATA	5.5 (1.3)	5.8 (1.0)	5.9 (0.9)	5.7 (1.0)	5.9 (1.0)
	TCATA Fading	5.8 (1.1)	6.1 (0.9)	5.9 (0.9)	6.1 (0.8)	5.8 (0.8)
	p-value	0.07	0.02	0.63	0.003	0.47
It was tedious to answer the questions	TCATA	1.8 (1.2)	2.5 (1.3)	2.9 (1.6)	2.5 (1.1)	2.6 (1.4)
	TCATA Fading	2.2 (1.8)	2.1 (1.1)	2.6 (1.5)	2.2 (1.1)	2.8 (1.3)
	p-value	0.1	0.04	0.33	0.1	0.56

that main difference between TCATA and TCATA Fading was found. Consistently, citation proportions were lower in TCATA Fading than TCATA (Tables 3 and 4), but the reason why is a key question left unanswered by the present research. Different perceptual and cognitive processes associated with selecting and un-selecting terms may play a role. If a term is not selected then clicking on it means that it applies, whereas if the term is already selected then it means that the term no longer applies. Thus, it could be that some assessors are more attentive to describing the onset of sensations than the offset of sensations. Similar findings have also been reported in other sensory modalities. In the auditory domain, Zera and Green (1993) tested participants' reaction time for detecting the onset of harmony asynchrony in music vs. reaction time for detecting the offset stimulus (i.e., ending of harmony asynchrony). The onset detection was 10× faster than the offset detection, suggesting that detection of offset be more difficult. In a visual experiment, Cole, Kentridge, Gellatly, and Heywood (2003) used images containing ~20 coloured geometrical objects, and reported that the average time it took participants to detect the addition of an object to the image (onset) was significantly faster than average time to detect the deletion of an object from the image (offset).

Furthermore, the task of checking a term that does not apply involves endorsing a term in a negative manner. In the field of sensory and consumer research there appears to be only a single study which considered this explicitly (Castura, Fortune, Phipps, & Findlay, 2013). These authors asked consumers to check sensory terms that applied, then to check terms that did not apply. Fewer terms were checked overall in the "does not apply" wording, and many terms that were not selected when the "apply" wording was used were also not selected when the "does not apply" wording was used. It is also possible that just as some TCATA assessors might fail to uncheck a selected term, some TCATA Fading assessors might fail to check a not-selected term. In both cases this could due to "satisficing" response behaviour, which is considered "weak" if the assessor believes that a suboptimal response is adequate, or "strong" if the response is arises from a superficial understanding or willingness to complete the task (Krosnick, 1991, 1999).

Despite differences in citation proportions, the dynamic profile of samples obtained using TCATA and TCATA Fading were highly similar. As shown in Figs. 2 and 3, the terms with the highest and lowest citation proportions were identical in the two TCATA variants. In terms of dynamic sensory profiles for the focal samples, the main difference between TCATA and TCATA Fading was related to the evolution of citation proportions over time.

TCATA Fading and TCATA differed in their ability to identify significant differences among samples. Across seven of the eight studies the percentage of all possible comparisons between pairs of samples that were significant throughout the evaluation was higher for TCATA than TCATA Fading (Tables 3v and 4v). However, the opposite trend was observed when the number of terms with significant differences for pairwise comparisons between samples was considered (Tables 3vi and 4vi). In six of the eight studies, TCATA Fading tended to identify significant differences among samples in a larger number of attributes than TCATA. As shown in Figs. 4 and 5, the time period during which differences between samples was significant was longer for TCATA than TCATA Fading, probably because assessors did not un-check terms immediately after they stopped perceiving them as applicable for describing samples. These results suggest that although both TCATA variants were able to identify the most relevant differences among samples, TCATA Fading may offer additional discrimination among samples.

The results pertaining to the dynamic sensory profiles and sample discrimination indicate another key question left unanswered by the present research: which of the two TCATA variants delivers more "correct" results? Tentatively, in the judgment of the authors of this paper, TCATA Fading is considered to provide a more realistic description of how the sensory characteristics changed over time than TCATA, especially for sensations that disappear after a certain period of time. For example, in Study 4 (milk desserts) citation proportion of the attribute *creamy* showed a clear maximum in the TCATA Fading task (around 12 s), which was not observed in the TCATA task (Fig. 3a). A similar result was observed for the attribute *hard* in Study 2 (salami: Fig. 2b). Future research specifically developed to compare the ability of TCATA and TCATA Fading to accurately capture the temporal evolution of sensory attributes. In this sense, comparison of temporal evolution for attributes obtained with time-intensity and TCATA could provide fundamental insights and serve as a baseline for comparison of TCATA and TCATA Fading.

Self-reported task-perceptions data revealed that consumers perceived both TCATA and TCATA Fading as "easy" and "not tedious", in agreement with previous studies (Ares et al., 2015). TCATA and TCATA Fading variant did not differ in perceived ease/difficulty of the task. Yet, in Studies 5 and 7 mean perceived ease of task scores were significantly higher for TCATA Fading than for TCATA, whereas in Study 7 perceived tediousness was significantly lower for TCATA Fading than for TCATA (Table 5). The differences between the two TCATA variants were relatively small, but could suggest that consumers prefer automatic un-selection of terms and having to select them again if they remain applicable for describing the product.

Future research could investigate whether there are differences in the two TCATA variants in task perception as task familiarity increases, for example during training of trained assessors. Qualitative debriefing of consumers could also provide a deeper understanding of task completion as experienced by participants, including perceived attention to selecting vs. un-selecting terms (TCATA variant) and having to re-select terms that still apply (TCATA Fading variant).

The present research represents a first attempt at implementing the TCATA Fading variant, and it is clear that many avenues for methodological refinement exist. Such options include consideration of how to best determine the pre-defined period of time until a selected term reaches the fully de-selected state. The fading duration is expected to depend on the duration of the evaluation, and on the characteristics of the dynamic profile of the product. In this study, an 8-s fade duration was considered for TCATA Fading, which is longer than the 3 s duration used by both Kuesten et al. (2013) and Thomas et al. (2015). The longer duration in the TCATA fade task was chosen to avoid making the task too difficult or too tedious for assessors who are required to consider and re-check attributes for as long as they are applicable for describing samples. The most appropriate fade time might depend on the number of terms. It could also be considered an option that different terms have different fading times to reflect their perceptual evolution. For example, bitterness and astringency may lapse slower than sweetness and acidity (Ishikawa & Noble, 1995; Lawless & Skinner, 1979; Lee & Lawless, 1991).

Further research should also study refinements in the data analysis of TCATA Fading data. If assessors, as suggested by the present results, do not immediately re-select a term that is still applicable a selected state can be inputted during this period of time. Such data imputation could be considered especially reasonable when an attribute is automatically unchecked, then re-checked after a short time gap. The completed data can be analysed and those results compared to the findings from TCATA. Thomas et al. (2015) use a similar approach for TDS data; they input a selected state to attributes during the time that elapses between deselection of one attribute and selection of the following attribute.

For completeness we note that the decrease in term citation proportions was more pronounced in studies involving consumers. However, this difference should not be ascribed to assessor type, since other factors varied between the studies with trained panellists and consumers, including product category, degree of sample differences, sample size, and evaluation duration. Furthermore, it was not a stated aim of this research to compare performance of trained assessors and consumers. Further targeted research is required to so investigate differences between assessor types.

5. Conclusions

This research compared two variants of the TCATA method. Results from the present work suggest that automatic de-selection of attributes in a TCATA task can improve discrimination and, in our opinion, provide a more accurate description of the dynamics of sensory characteristics of products than asking consumers to de-select attributes when they are no longer applicable. The influence of degree of difference among samples in the relative performance of TCATA Fading relative to regular TCATA deserves further exploration.

Author contributions

All authors contributed to the development of the research. G. A., L.A., J.C.C. and S.R.J. wrote the paper. G.A. and L.A. analysed the data.

Acknowledgments

Financial support for studies conducted in Uruguay was received from Comisión Sectorial de Investigación Científica (Universidad de la República, Uruguay). For studies conducted in Argentina financial support was received from Secretaría de Ciencia y Técnica of Universidad de Buenos Aires. For the study conducted in New Zealand, financial support was received from The New Zealand Ministry for Business, Innovation & Employment and The New Zealand Institute for Plant & Food Research Ltd. Staff in the Sensory and Consumer Science Team at Plant & Food Research are thanked for help in collection of data.

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