Received: 20 September 2023 | Revised: 7 December 2023 | Accepted: 16 December 2023

DOI: 10.1111/1541-4337.13294

COMPREHENSIVE REVIEW

Comprehensive REVIEWS in Food Science and Food Safety WILEY

Multi-attribute temporal descriptive methods in sensory analysis applied in food science: A systematic scoping review

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Abstract

Among descriptive sensory evaluation methods, temporal methods have a wide audience in food science because they make it possible to follow perception as close as possible to the moment when sensations are perceived. The aim of this work was to describe 30 years of research involving temporal methods by mapping the scientific literature using a systematic scoping review. Thus, 363 research articles found from a search in Scopus and Web of Science from 1991 to 2022 were included. The extracted data included information on the implementation of studies referring to the use of temporal methods (details related to subjects, products, descriptors, research design, data analysis, etc.), reasons why they were used and the conclusions they allowed to be drawn. Metadata analysis and critical appraisal were also carried out. A quantitative and qualitative synthesis of the results allowed the identification of trends in the way in which the methods were developed, refined, and disseminated. Overall, a large heterogeneity was noted in the way in which the temporal measurements were carried out and the results presented. Some critical research gaps in establishing the validity and reliability of temporal methods have also been identified. They were mostly related to the details of implementation of the methods (e.g., almost no justification for the number of consumers included in the studies, absence of report on panel repeatability) and data analysis (e.g., prevalence of use of exploratory data analysis, only 20% of studies using confirmatory analyses considering the dynamic nature of the data). These results suggest the need for general guidelines on how to implement the method, analyze and interpret data, and report the results. Thus, a template and checklist for reporting data and results were proposed to help increase the quality of future research.

KEYWORDS

FAIR, guidelines, sensory evaluation, temporal methods

1 | INTRODUCTION

1.1 | Rationale

Sensory qualities of food have been reported worldwide as the most important factor in food choice (Caltabiano & Shellshear, 1998; Glanz et al., 1998) and purchase (Allès et al., 2017; Glanz et al., 1998; Honkanen & Frewer, 2009; Januszewska et al., 2011; Milošević et al., 2012). This makes the study of the sensory response to food and beverage central to the understanding of eating behaviors (Forde, 2016) and developing sustainable foods (Aschemann-Witzel et al., 2019; Hoek et al., 2017; Knaapila, 2022).

The transformation of food in the mouth results in complex mixtures of information involving the senses of smell, taste, trigeminal, and touch. Each sense perceives and translates the information independently and dynamically integrating it into a continuous perceptual output (Forde, 2016). Measuring this continuous perceptual output has been an objective since the early development of sensory science. Indeed, even the most advanced analytical techniques of quantification of physicochemical properties of foods cannot replicate the complexity of the human sensory perception (Forde, 2016). Thus, all sensory evaluation methods rely on subjects' self-reported measurements (Torrico, 2021) that are expected to be representative of the sensory properties of products (Lahne, 2018).

Providing data that meaningfully reflects a complex real-world experience using a task that subjects are able to perform successfully is challenging (Castura, 2018). Over the years, numerous sensory evaluation methods have been developed attempting to dynamically measure perception during the tasting of food products getting as close as possible to the moment when sensations are perceived. Entire books devoted to such temporal sensory evaluation methods were written (Castura, 2018; Kemp et al., 2017) but there are still gaps and needs for guidelines over different aspects that have not been covered.

To date, only narrative reviews have been carried out on temporal sensory evaluation methods (Cliff & Heymann, 1993; Devezeaux de Lavergne et al., 2017; Di Monaco, Su et al., 2014; Dijksterhuis & Piggott, 2000; Fiszman & Tarrega, 2018; Foster et al., 2011; Keefer et al., 2023; Schlich, 2017), particularly on those focused on product description using more than one attribute (multi-attribute descriptive methods). Unlike narrative reviews, systematic scoping reviews are structured based on a rigorous methodology (Visalli & Galmarini, 2022) and include a risk of bias assessment, which makes the results transparent, reproducible, and objective.

1.2 | Objectives

Based on the scoping review methodology, the aim of this article is to draw up an exhaustive and objective inventory of the methods available for multi-attribute temporal descriptive sensory evaluation of food products. We chose not to consider single-attribute temporal descriptive sensory evaluation methods such as time–intensity (TI) (Lee & Pangborn, 1986) because of their specific use due to the limitation of measuring only one attribute at a time. Moreover, since TI is simpler (only one attribute) and was developed decades before the multi-attribute temporal methods, it was already well documented (Cliff & Heymann, 1993; Dijksterhuis & Piggott, 2000) with a high agreement in the sensory community regarding its implementation and analysis. Thus, this review covers (i) the development and use of multi-attribute temporal sensory evaluation methods, (ii) their implementation, (iii) the analysis of temporal sensory evaluation data, (iv) methods comparison, and (v) the diffusion of results. Beyond informing actual practices and disseminating research findings, the ultimate objective is to identify research gaps in the existing literature and draw recommendations for future research.

2 | METHODOLOGY

2.1 | Protocol and registration

2.1.1 | Summary of the original protocol

This scoping review was conducted according to the PRISMA Extension for Scoping Reviews (PRISMA-ScR, Tricco et al., 2018). It was registered, reviewed, and published in PLoS ONE (Visalli & Galmarini, 2022). Hereafter is a summary of the original reviewed and published protocol (Figure 1).

The main criteria for inclusion were research articles, available in Web of Science and/or Scopus, referencing multi-attribute temporal descriptive sensory evaluation methods, related to the evaluation of food and beverages (nonfoods were considered out of scope) or to methodological/data analysis issues. Further details and research equations can be found in Visalli and Galmarini (2022).

2.1.2 | Changes made to original protocol

Compared to the original protocol, some changes have been made. The period for article inclusion was extended to include all those published in 2022. The "Number of citations" was replaced by Field-Weighted Citation Impact (FWCI, Purkayastha et al., 2019). This metric is the ratio of

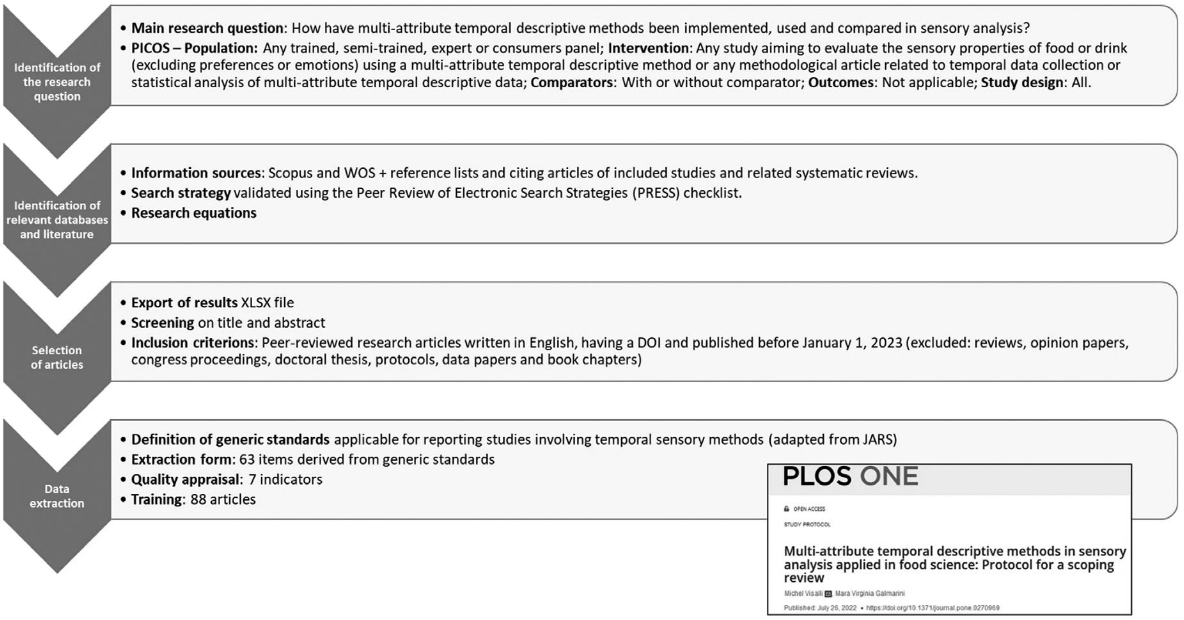

FIGURE 1 Main steps of the reviewing process.

the total citations actually received by the article and the total citations expected based on the average of the subject field. A FWCI lower than 1 means that the article is cited less than expected, whereas an FWCI greater than 1 means that the article is cited more than expected.

2.1.3 | Quality appraisal of the included articles

The risk of bias was evaluated for each included article. For the purpose of transparency and reproducibility, the main reasons for "no" reported by the two authors for the seven quality criteria were analyzed (Q1–Q7, see Table 1), and specific reasons were determined by consensus for deciding not to check each quality criterion. If at least one specific reason was identified by the two reviewers, the quality criterion was not checked. Then, the number of quality criteria checked was computed for each article. It is to be reminded that the quality evaluation of the papers was made only in relation to the research question on multi-attribute temporal evaluation methods. Therefore, in those works were the multi-attribute temporal methods were only a part of the paper, the quality appraisal was done in relation to this and not the whole paper.

2.1.4 | Data analysis

Data included in the extraction form (see Visalli & Galmarini, 2022) were grouped, counted, and analyzed with pivot grid using Excel 365. All figures were plotted using Excel 365.

2.2 | PRISMA diagram

After the identification, screening and eligibility steps, a total of 363 published articles were included in this scoping review (Figure 2). It is to be noticed that the large number of studies found with the research equations was due to the use of acronyms and keywords having different meanings in the field of food science.

To contextualize the relative importance of temporal methods in the landscape of descriptive sensory evaluation methods, a research was made in Web of Science (limited to the field "Agricultural and Biological Sciences") on Descriptive Analysis (DA) and Check-All-That-Apply (CATA; Adams et al., 2007), the most used static quantitative and qualitative methods. A total of 3247 articles were found for DA and 637 for CATA. Even including time–intensity (TI; Lee & Pangborn, 1986), it can be roughly estimated that temporal methods were used in about 10% of the articles referencing descriptive sensory evaluation methods.

3 | RESULTS AND DISCUSSION

3.1 | Included articles

The included articles (Tables A–C) were classified in three categories depending on their main objective: methodological (new method or variant, comparison of method, details of implementation), data analysis (including data processing), and other (all articles having the objective to gain knowledge on products, food oral processing, fundaments of perception, etc.)

TABLE 1 Reasons for not checking quality criteria.

Quality criterion	Main reasons for criteria not to be checked
Q1: Clear research question?	No justification of the use of the temporal method Missing key bibliographic references (e.g., reference to the temporal method) No justification of the relevance of the research
Q2: Appropriate participants?	Less than 20 evaluations (*subject* x *replicates*) of the products Lack of information on consumer panel (e.g., nothing about selection criteria and demographics) Number of evaluations not reported and number of subjects lower than 20
Q3: Appropriate design and data collection?	Product and attribute presentation orders not reported Instructions given to perform the temporal tests not reported Inappropriate design for treatment comparison (e.g., unbalanced within-subject design for method comparison) TDS-I with no later use of intensity scores Unclear tasting protocol making it non-reproducible Inappropriate attributes (e.g., "aftertaste" for TDS)
Q4: Appropriate data analysis?	Conclusions based only on exploratory analysis Unclear data analysis making it non-reproducible Unjustified data selection (e.g., subject removal) Inappropriate data transformation
Q5: Claims supported by evidences?	No substantial evidences or conclusion not congruent with findings Unjustified selective reporting (e.g., results not reported for some products) Low quality figures Errors in reporting of results
Q6: Integrated interpretation and conclusion?	No limitation reported No connection with previous works reported No discussion on the relationships between all data collected in the case of multiple data acquisition (e.g., link between physicochemical and temporal sensory description of products)
Q7: Useful contribution?	No contribution to the field reported

3.2 | Development and use of temporal sensory evaluation methods

3.2.1 | History of development of temporal sensory evaluation methods

The first descriptive method that considered the temporal aspect was TI. The reference research paper on the method is from 1986; however, this method was first implemented in 1945 (Sjöström, 1954) and was more efficiently used later thanks to the development of computerized systems.

After TI, many methods were developed aiming to describe products in a temporal fashion using more than one descriptor. Table 2 shows a total of 23 methods that were developed and published after TI up to December 2022.

It took many years to come up with a method which could allow assessors to perform a wider description using more than one attribute. Following the TI paradigm, the older multi-attribute methods (PP, A-TI, DATI, SP, and MATI, see Table 2 for acronyms) were intensity-based. However, these methods were not widely used: only a total of 38 published articles were found, representing 10% of the articles of the present scoping review. This raises concern about the methods' difficulty of use for panelists (Meiselman et al., 2022). Moreover, it could be possible that, at the moment when these methods were introduced, researchers expected to get information on many attributes (influenced by the static DA method, which has a wide list of attributes) or with a high level of detail as in TI and this could have impacted on the way the experiments were designed and analyzed.

It was only in 2008 (publication date of first research paper though the method was presented before at the 5th Pangborn Symposium as Pineau et al., 2003) that a change of paradigm was introduced with TDS (Table 2). This method proposed a description based on the tracking of dominant attributes stating one dominant attribute at a time. To date, the most used definition of a dominant attribute is "the attribute that triggers the attention (i.e.,

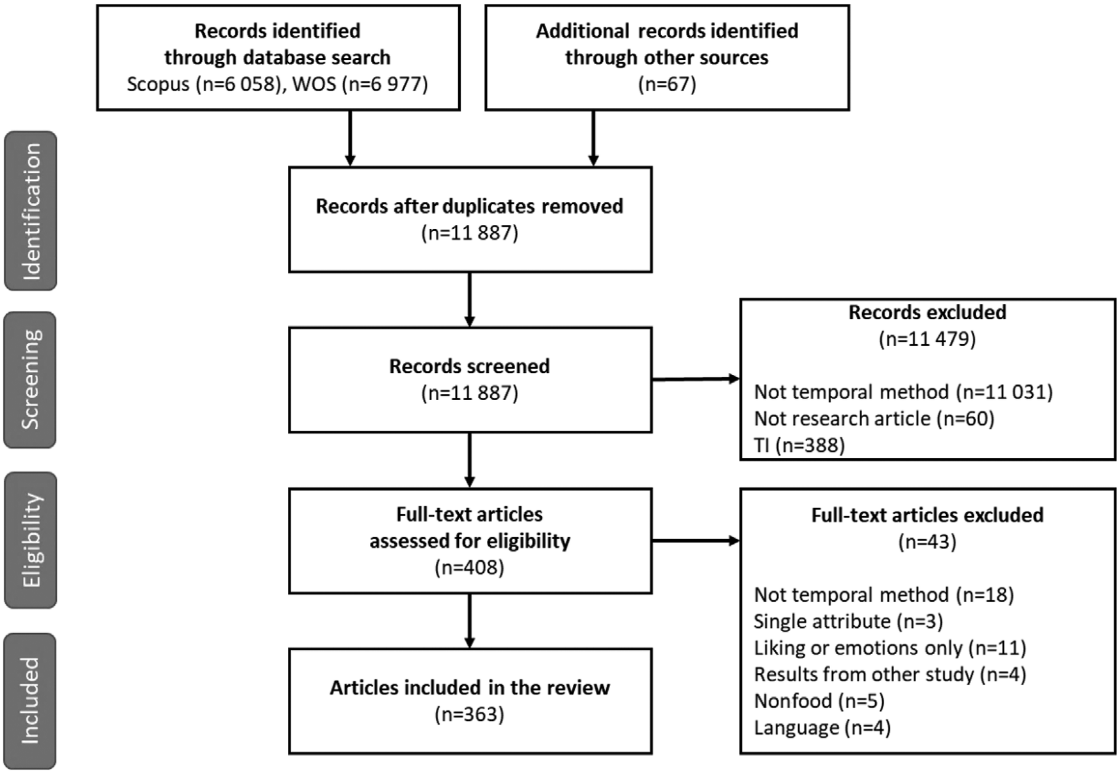

FIGURE 2 PRISMA diagram for article identification, selection, and inclusion.

most striking perception at a given time), not necessarily the most intense" (Pineau et al., 2009), but several definitions can be found in the literature (Hutchings et al., 2022; Varela et al., 2018). Originally, subjects were also asked to rate the intensity of the dominant attributes (TDS-I) as it was done with all the methods before, but the rating task was deemed too difficult (Schlich, 2017) and the intensity rating was no longer recommended, and TDS-I became TDS.

In 2015, TCATA was developed (Table 2) looking to overcome the limitation inherent to the concept of dominance that imposes subjects to choose and report only one attribute at each time. TCATA enables the tracking of all perceived (applicable) sensations. In this way, the path of temporal methods continued to evolve in the direction of qualitative evaluations. TCATA also assumes that when a sensation is no longer perceived, assessors will uncheck the corresponding attribute. This last assumption was difficult to prove (Ares et al., 2016) given that the cognitive task of "unchecking" (stating absence of sensation) is quite different from "checking" (being vigilant of the new perceived sensations). Trying to cope with this, the fading alternative was introduced (TCATA-F, Table 2) considering that after a certain time the sensation will no longer be applicable and thus the attribute is automatically unchecked, freeing the panelist from this task. The time elapsed from check to automatic uncheck (fading time) is determined by the experimenter and not by the evaluator.

New variants of TDS and TCATA were developed afterward (Table 2). These include TDS evaluations with the possibility of indicating two attributes at a time (instead of only one) given that they corresponded to different sensory modalities (Dual TDS). Another variant considers the possibility of having periods of "non-dominance" (TDS-HD). Discrete time variants of TCATA have been proposed, still trying to avoid the limitation that comes from (not) unchecking attributes (D-TCATA). To limit the number of attributes simultaneously tracked and avoid favoring the sensory modalities easier to identify (e.g., texture vs. flavors), both TDS and TCATA proposed variants consisting in evaluating successively the different sensory modalities (M-TDS and M-TCATA).

Recently, new qualitative methods (Table 2) summarizing the perception in several periods were proposed (AEF-D, AEF-A, FC-AEF-A, Quessence, F-TOS). The rationale behind these retrospective evaluation methods (by opposition to concurrent evaluations in continuous or discrete time) is to simplify data collection and analysis by sacrificing temporal resolution (TR). Finally, TR (Table 2) is in-between qualitative and quantitative measurements, as the method asks subjects to rank the perceived attributes according to their intensity at each time (TR).

TABLE 2 Descriptive temporal sensory evaluation methods, acronyms used, date, and reference of first publication in a research paper and number of articles in which the method has been used until December 2022 (several methods can be referenced in a same article).

Method name and acronym	Reference paper	Number of articles
TI: (single-attribute) time–intensity	Lee and Pangborn (1986)	414[a]
Multi-attributes intensity-based methods		38
PP[b]: Progressive profile	Jack et al. (1994)	18
DATI: Dual-attribute time–intensity	Duizer et al. (1996)	4
A-TI: Alternated time–intensity	Pionnier et al. (2004)	1
SP: Sequential profile	Methven et al. (2010)	12
MATI: Multi-attribute time–intensity	Kuesten et al. (2013)	2
TDS-I: Temporal dominance of sensations with intensity	Le Révérend et al. (2008)	35
TDS and variants		255
TDS[c]: Temporal dominant of sensations	Pineau et al. (2009)	241
M-TDS: TDS by modality	Agudelo et al. (2015)	13
TDS-HD: TDS hold down	van Bommel, Stieger, Schlich, et al. (2019)	1
TDS-D: Dual TDS	Pittari et al. (2022)	1
TCATA and variants		70
TCATA: Temporal check all that apply	Castura, Antunez et al. (2016)	54
TCATA-F: TCATA fading	Ares et al. (2016)	15
D-TCATA: Discrete time TCATA	Visalli et al. (2022)	2
M-TCATA: TCATA by modality	Dietz, Cook, et al. (2022)	1
M-TCATA-F: TCATA fading by modality	Barker and McSweeney (2022)	1
Other qualitative methods		7
TQT: Time-quality tracking	Zwillinger and Halpern (1991)	1
AEF-D: Attack-evolution-finish with dominance	Visalli et al. (2020)	1
FC-AEF-A: Attack-evolution-finish with applicability with free comment	Mahieu et al. (2020)	1
AEF-A: Attack-evolution-finish with applicability	Visalli et al. (2022)	1
Quessence	Jeltema et al. (2020)	1
F-TOS: Free temporal order of sensations	Carrillo et al. (2021)	1
TR: Temporal ranking	Keefer et al. (2022)	1

[a]This number includes 388 articles referencing only TI (out of scope of this review), plus 26 referencing TI, and other temporal methods (in the scope of this review).
[b]Progressive profile was found also as "Dynamic profile," "Fixed-time profile intensity," "Discrete time–intensity," but in all the cases the principle was the same.
[c]TDS was found as "Temporal dominance of pungency sensations" in one publication.

These first mentioned results show there may be a delay between the first presentations of methods (often at congresses) and their validation by peers (publication). Some temporal methods have never been published in a peer-review journal (e.g., Temporal Order of Sensations, Pecore et al., 2011; Pick-3-And-Rank, Vandeputte et al., 2011) and thus probably never reused by other people. It can also be noticed that some identical methods were named in different ways, probably because the authors "reinvented" them without knowing it. Finally, ongoing developments of temporal methods suggest that there are needs that are still not being met and that there is room for improvement in the field.

3.2.2 | Main characteristics and differences of temporal sensory evaluation methods

Based on the previous description on the evolution of multi-attribute temporal methods, it is clear that they are not all based on the same paradigm, nor do they integrate time in the same fashion. In fact, temporal methods can

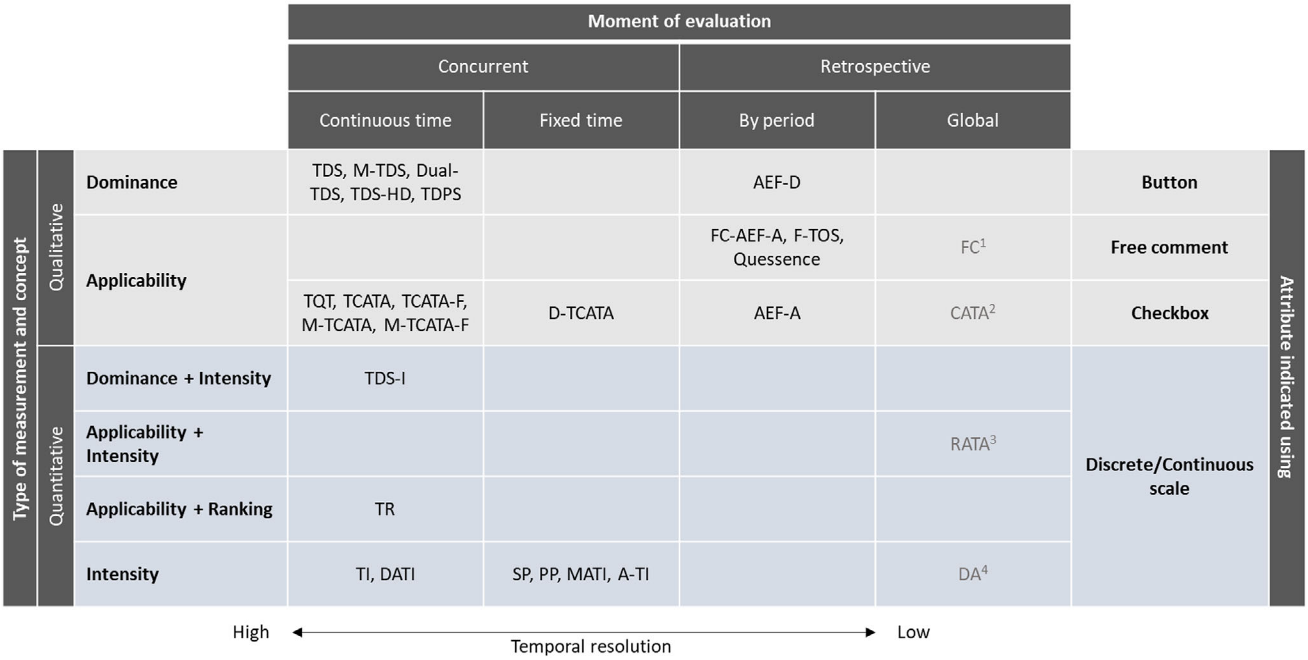

FIGURE 3 Main characteristics of descriptive sensory evaluation methods. Gray text: static methods: [1]free comment; [2]check-all-that-apply; [3]rate-all-that-apply, [4]descriptive analysis. See Table 2 for other acronyms.

be grouped based on two main characteristics: the type of measurement which can be associated with qualitative (dominance and applicability) or quantitative (intensity) concepts, and the moment of the evaluation. Figure 3 presents the different sensory methods resulting from the combination of these characteristics.

When products are evaluated globally in a retrospective manner with no particular consideration of the temporality of perception, the descriptive method is considered static (e.g., free comment, CATA, rate-all-that-appliy, DA—all of them out of scope of the present article). On the other hand, an evaluation can be retrospective but considering and recalling the sensations perceived during specific temporal periods of the evaluation. For example, in AEF (and its variants, see Table 2) the periods are attack, evolution, and finish (giving origin of its name), whereas in F-TOS the three first sensations are considered.

The so-called dynamic methods ask subjects to report their perception concurrently to the tasting, either at predefined discrete times (D-TCATA, PP, MATI, and A-TI) or over a continuous window of time (TDS, TDS-I, TCATA, TQT, and TR). In dynamic methods, the subjects' reaction time is key, this is why attributes are chosen beforehand by the experimenter and are presented as a list (see Section 3.3.4 for details on attribute choice). It is evident that the challenge of keeping the attribute list manageable for the assessors and yet detailed enough for sample description and discrimination, makes attribute selection a key step when designing a TDS experiment. It should be taken into account that an incomplete or not representative list can lead to dumping effect that, in the case of TDS, would produce an illusory enhancement in the choice of one attribute as dominant only because assessors have a restrictive list from which to choose. As in traditional sensory profiling, dumping effect is especially important when a conspicuous attribute that varies across the samples was omitted (Lawless & Heymann, 2010). Retrospective measurements lose in TR but, as an advantage, they allow for a different choice of descriptors, such as free comment instead of predefined list of attributes, which could reduce the dumping effect that could result from a poor list of attributes.

3.2.3 | Use of temporal sensory evaluation methods over years

All the presented multi-attribute temporal methods have not been used with the same frequency over time. Figure 4 describes the number of articles that have used each multi-attribute descriptive method by year of publication. TI is presented for the purpose of comparison.

It can be observed that TDS (and all the variants that do not include intensity rating) is the most frequently used method followed by TCATA (and related variants). Their use increased over time, showing their adoption by the sensory community. After a peak in 2021 (72 articles), a slight slowdown is observed in 2022, which seems

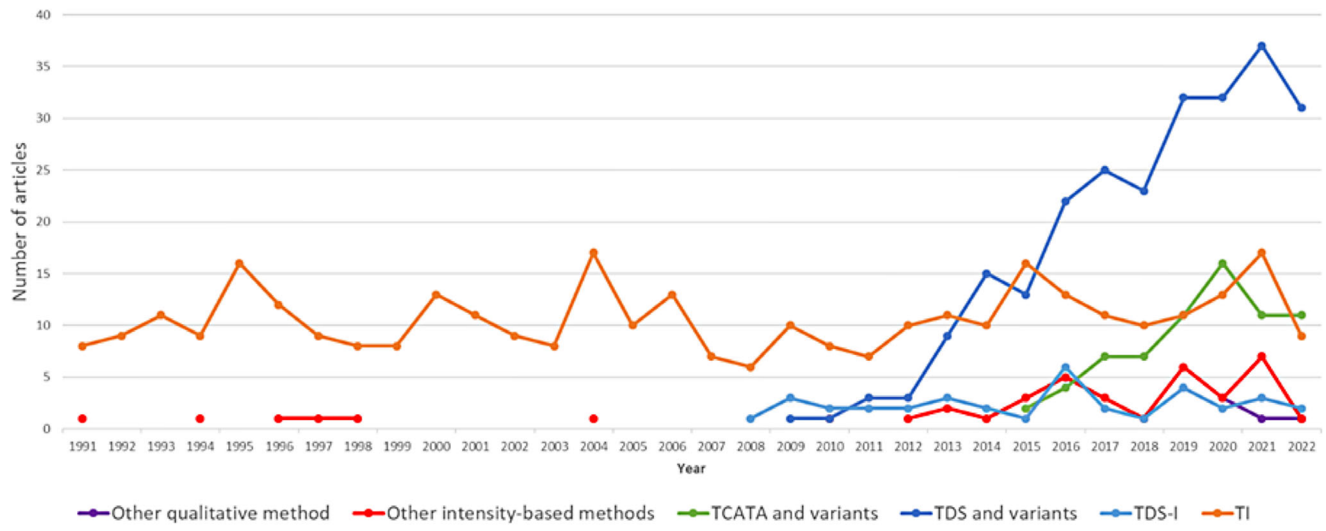

FIGURE 4 Number of articles published by year and type of temporal method used.

to be confirmed in 2023 (38 articles published from January to August, not represented on Figure 4). Nonetheless, multi-attribute temporal methods did not replace TI that has been used in a constant manner over the past three decades. Despite the recommendations given on the rating of dominance intensity (Schlich, 2017), TDS-I continued to be used after this date.

3.3 | Implementation of temporal sensory evaluation methods

3.3.1 | Aim of the research

Multi-attribute temporal descriptive methods were present in papers with different objectives.

Figure 5 summarizes the main applications of temporal measurements of perception in food science, showing the central role of multi-attributes temporal evaluation methods. Most studies (70%) were interested in assessing the impact of food properties (physicochemical, structural and microbiological properties process, composition, association of foods, etc.) on measured sensory properties, expected representative of individual sensory perception (taste, flavor, texture/mouthfeel, and trigeminal sensations). The influence of several other factors on these measured sensory properties was also studied: successive consumption and quantity consumed, subjects' physiological state (saliva composition, sensitivity) and characteristic (age, gender, culture, knowledge and familiarity with food, etc.), in-mouth mechanisms (food oral processing: food breakdown, saliva flow, bolus formation; flavor release; cross-modal interactions; etc.), context of tasting (location, environmental sound, external information, temperature of the room, etc.), the details of implementation of the sensory evaluation method (type of method, training, number of subjects/attributes, definition of the task, etc.), or of the data analysis method (including data processing and interpretation of outputs). The impact of the sensory properties on other measurements was also studied: on affective properties triggered by food (liking, wanting, and emotions), on perceived sensory complexity (not represented in Figure 5), and on physiological state (satiety), food choices, and food intakes.

It should be noticed that authors' use of keywords did not add information that could contribute to the identification of the area of knowledge studied. In most cases, keywords repeated elements of the title or were too generic. The 10 most frequently used keywords were "Consumers," "Sensory," "Sensory characterization," "Temporal methods," "Sensory analysis," "TI," "Texture," "Oral processing," "Temporal check-all-that-apply (TCATA)," and "Temporal dominance of sensations (TDS)." Thus, keywords should be used as recommended by editors, avoiding repetition of words present in the title, and including relevant and controlled vocabulary (Ishida et al., 2020).

About 20% of the articles (Table A) reported methodological developments (either new methods, modifications of existing ones or methods comparison). In the past 5 years (2018–2022), this percentage decreased only to 15%, remaining as an area of interest showing that temporal measurements have not reached methodological maturity yet.

Regardless of the area of knowledge, in 45% of the evaluated papers, the temporal method was not the primary focus of the article but secondary to other sensory evaluation methods or to non-sensory measurements.

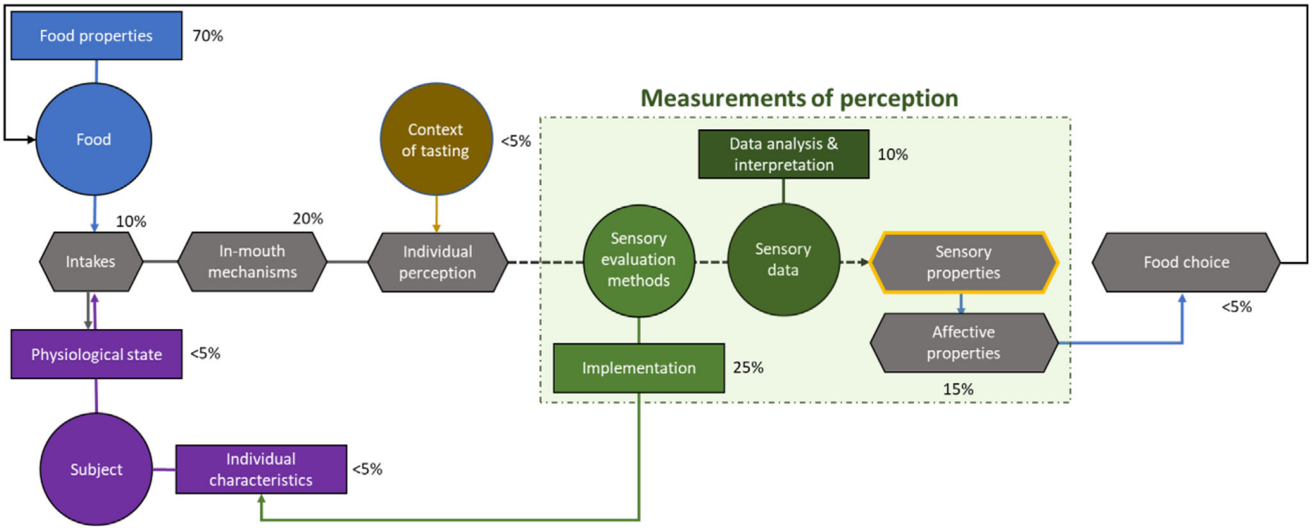

FIGURE 5 Main objectives of the use of temporal methods (as reported in the introduction of the articles). Numbers indicate the percentage of articles having related descriptive temporal sensory measurements with other objects of interest. An article can have multiple objectives.

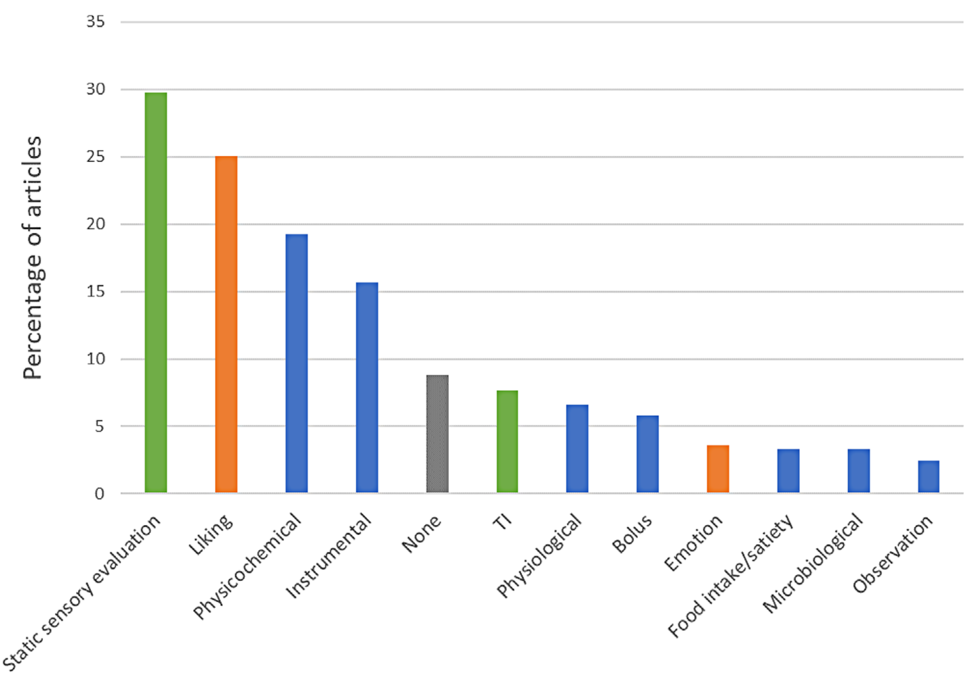

FIGURE 6 Other measurements found in articles which had multi-attribute temporal descriptive measurements (green: other sensory evaluation measurement and orange: affective measurement). Different measurements can be presented in one article.

Figure 6 presents the most frequent observed measurements done together with multi-attribute temporal measurements. Most product-oriented research used also instrumental analysis (e.g., rheology), physicochemical (e.g., chromatographic profiling), or microbiological characterization, whereas most subject-related measurements involved surveys or observational methods. Other measurements of perception include other explicit measurements (sensory evaluation methods such as temporal or nontemporal descriptive, discriminative, or hedonic tests), but also implicit measurements (EEG or face reading).

The use of such varied complementary measurements, together with the different aims of the works, shows that multi-attribute temporal methods are used for many different purposes and, probably, by sensory scientists with different levels of training and knowledge. Moreover, it implies that the resulting papers have a complex matrix of methods that require expert reviewers from each different area in order to have quality research.

3.3.2 | Type of products

The information collected on the evaluated samples included whether there was at least minimal information characterizing them, if information on the samples was given to the assessors and whether there was information regarding the serving conditions (possible answers: yes/no/not applicable), the origin of the samples (commercial or model), their physical state (liquid, semisolid, and solid), and the global product category (e.g., chocolate, strawberries, and gouda cheese).

The product categories were first transcribed as presented in the research paper and were then regrouped into more general categories (e.g., "dealcoholized wines" and "sparkling wines" were regrouped as "wines"). In this way, some detail on the products was lost but it allowed a better global representation of the information.

Figure 7 shows that among the 58 categories of products, solid (45%) and liquid products (40%) were evaluated almost with equal frequency, whereas semisolids (mainly dairy products) represented a minority (15%). About 1/3 were noncommercial samples including model solutions and products specifically designed for research purposes. The most frequently evaluated solid products were chocolate, cheese, bread, and fresh and deli meats. As for liquid products, those with a higher presence were wines, protein beverages, coffee, and beer. Surprisingly, although some food combinations have been studied, few composite prepared meals have been evaluated using temporal methods.

Figure 8 shows the distribution of the number of products per study. The most frequent number of products were 4 and 6. It should be noted that there were 13 studies were only one product was evaluated.

In the evaluated research articles, almost all products were evaluated in blind conditions (only four gave information on the products to the assessors). No information about the serving conditions (such as portion size, product temperature, type of light, blind/informed conditions, number of products per session, etc.) was presented in about 10% of the papers although this information is very important specially for the reproducibility of the experiment. Moreover, when possible, providing detailed information about products' composition (ingredients, nutritional facts, etc.) would allow the reusing of data for other purposes (e.g., investigating relationships between formulation and perception).

3.3.3 | Type of panels

To better understand the characteristics of the assessors participating in experiments with multi-attribute temporal methods, the following information was registered from the 363 articles: whether authors had presented the criteria for subject selection, the basis for the choice of the panel size and the number of participants involved, the recruitment modalities, demographic information on the final panel, the nature of compensation (if any), the type of panel considered (consumer, semi-trained, trained, and expert), and the training received.

Figure 9 shows the evolution over the last 10 years of the type of panels used to carry out the multi-attribute temporal descriptive measurements. The timeline begins in 2013 because, before that date, almost 100% of studies used trained panels. Regardless of the type of method used, it can be observed that most evaluations were performed by assessors with some kind of training (trending from 80% to 60% in the last 10 years). Consumer panels were implemented in around 30% of the evaluations, whereas the use of expert panels remained marginal. As a general trend, the use of trained/semi-trained panels slowly decreases over years, whereas the use of consumer panels increases. However, the use of trained panels remains the norm, except with the newly introduced qualitative methods specifically designed to be used by consumer panels (in particular AEF variants). In detail, overall intensity-based methods and TDS-I were used with trained/semi-trained panels in 85% of studies, TDS and variants in 70%, and TCATA and variants in 60%.

The fact that panels were considered trained, semi-trained, or consumers is related precisely to the level and type of training and to what authors mentioned as the type of panel they used; however, this information was not expressed in a unified fashion across papers (Figure 10).

The definition of the panel (trained or semi-trained) was sometimes given by the authors but without being supported by the information on the type of training. In other cases, the training task was mentioned but there was no reference to the time devoted to it. This made it difficult to objectively classify and distinguish between trained and semi-trained. This is why, even though these two types of panels are different, they were grouped in the present scoping review.

In terms of the training, 25% of the articles working with trained or semi-trained panels did not mention any information. The papers that did report training mentioned durations that could range from very short (2 h or less)

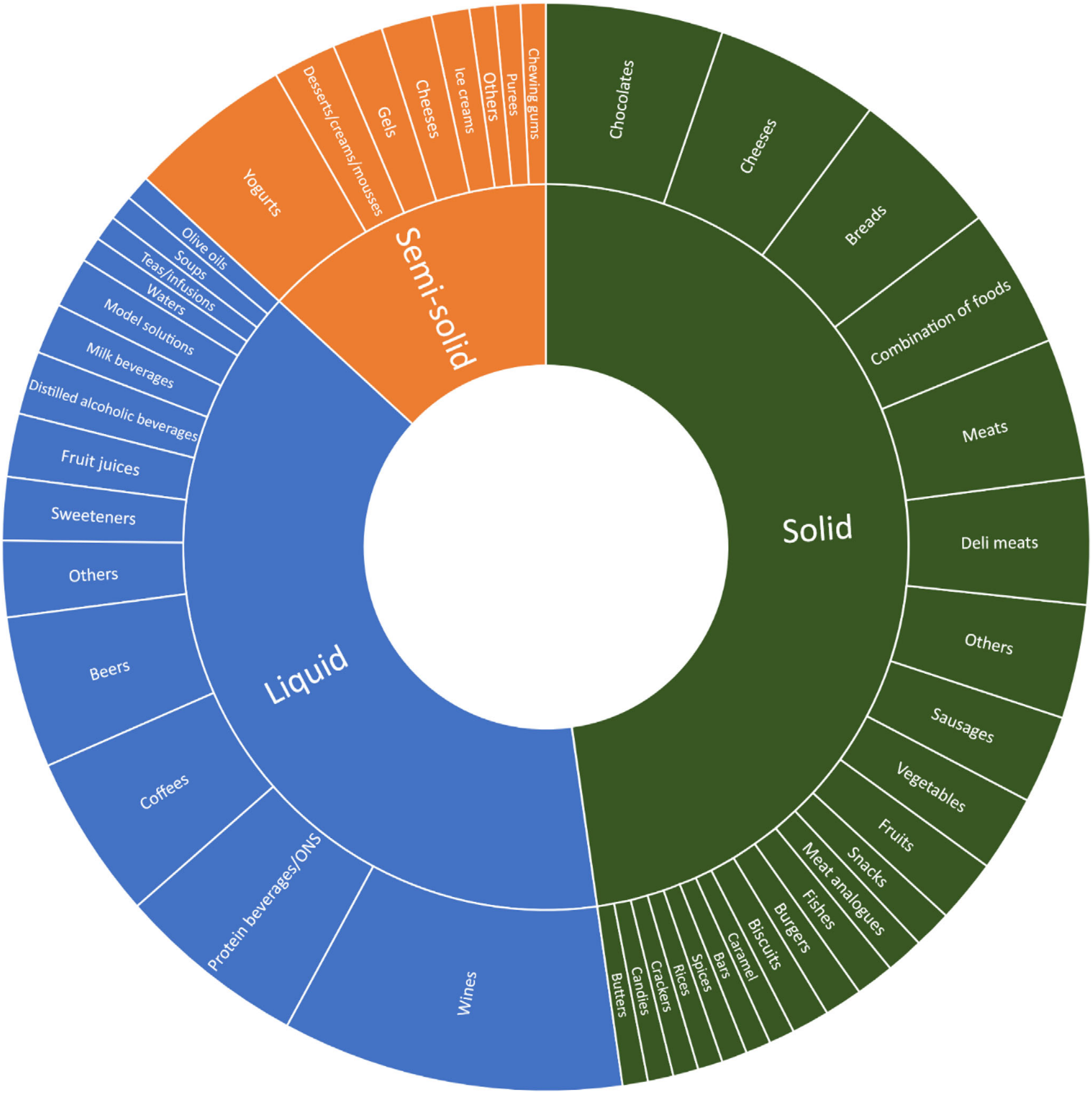

FIGURE 7 Categories of products evaluated using multi-attribute temporal methods. Only categories of products referenced in articles interested in the impact of food properties on sensory properties (see Figure 5) are included.

to long periods (more than 10 h). As could be expected, there were disparities between the different types of methods. For intensity-based methods and TDS-I, the most frequent training duration was more than 10 h. For TDS and TCATA, about 50% of studies (among those having reported the information) included a training of 2–4 h. Almost 10% of trained/semi-trained panels were defined as such based on previous experience with other DA, different from the temporal method that was actually carried out. Only 15% of articles (not represented on Figure 10) involving trained or semi-trained subjects reported results on panel repeatability. It would seem that replicates were collected to "artificially" increase the sample size and not to check panel consistency (as it is the case in static descriptive methods).

More than half of consumer panels (55%) received a familiarization training (i.e., a short introduction to the attributes and some preliminary tests before the final test, (Jaeger et al., 2017; Rodrigues, de Souza et al., 2016) before evaluating the products. However, details on the duration

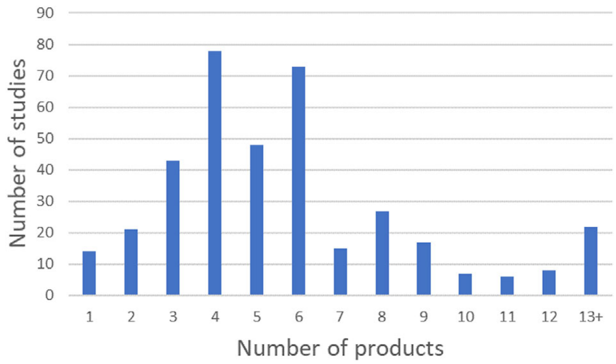

FIGURE 8 Distribution of number of products per study. An article can reference several studies involving different number of products.

of this process were not presented. It is to be noted that two studies investigated the impact of familiarization on the capacity of subjects to discriminate between products, but their results were contradictory (Jaeger et al., 2017; Rodrigues, de Souza et al., 2016).

Other than training, there are certain practices that are usually incorporated in descriptive measurements to improve the quality of the obtained data. These include giving a warm-up or dummy sample to evaluators for them to get acquainted with the method before the evaluation, using physical references to better understand and increase agreement on attribute perception and description, and giving definitions of the used attributes also to improve consensus among subjects. These practices were checked in all the evaluated papers and it was found that references were reported in 25% of studies (35% with trained/semi-trained panels), definitions in 45% (55% with trained/semi-trained panels), and warm-up in only 15%. These values are surprisingly low for descriptive methods, but it could be argued that these practices are held regularly but are not detailed in the research papers. It could be considered an activity which is part of a "previous training." However, it is a good practice to use references and definitions to get the panel agreement and this should always be reported in order to stimulate this use in all future research.

About 10% of consumer studies were done out of laboratory. A few studies investigated the influence of data collection settings on temporal measurements (Dinnella et al., 2022; Kantono et al., 2018; Xu et al., 2019b). Measuring perception in natural settings is desirable to evolve toward more ecologically valid data. However, these uncontrolled settings potentially introduce new bias that have to be identified, and replication studies are needed before generalizable conclusions can be drawn.

Figure 11a shows the distribution of the number of subjects by study depending on the type of panel. The means of the number of subjects are about 70 for consumers, 9 for experts, and 15 for trained/semi-trained subjects. The choice of the number of assessors, regardless of the type of panel, was not explained or justified in about 95% of the published papers. In less than 5% of the articles, the choice was made based on literature recommendations. Finally, a tiny minority (<1%) justified their choice based on power calculation.

Figure 11b shows the distribution of the number of evaluations by study depending on the type of panel. The means of the number of evaluations are about 75 for consumers (mode = 1 replicate), 15 for experts (mode = 3 replicates), and 38 for trained/semi-trained subjects (mode = 3 replicates). The wide range evidences the lack of agreement on the most adequate number of participants/evaluations, which is more evident when working with consumers. For these, the number 70 was probably chosen in reference to the minimum number of tasters recommended for hedonic tests (Hough et al., 2006; Mammasse & Schlich, 2014) or other descriptive tests involving consumers (Ares et al., 2014).

Recommendations are scarce in the literature regarding the number of subjects needed for the evaluations. Pineau et al. (2012) recommended for TDS about 16 trained subjects and two or more replicates to have at least 30 evaluations. Relating the use of replicates with the total number of evaluations instead of the consistency of the panel might be one of the reasons why experimenters do replicates with a different goal than in static descriptive methods: looking to increase the evaluations but not checking for consistency. Cheong et al. (2014) suggested for TDS at least 15–20 untrained panelists evaluating samples in triplicate. Okamoto (2021) showed that standard error around citation rates is correctly estimated in TDS curves with samples of sizes larger than 100 (samples of size 50–100 being acceptable). Again, it seems that the conclusions on the best number of subjects and evaluations depend on various factors (sensory complexity of the product, size of the differences between products, expected TR for product characterization, etc.). In any case, it seems reasonable to consider that compared to a static sensory evaluation (in which no temporal measurements are collected), a larger number of panelists is required to draw solid conclusions related to temporal aspects of perception.

Finally, the criterion for subject selection, the recruitment modalities, the demographics of subjects and the nature of the compensation were reported in 80% (75% with trained/semi-trained panels and 90% with consumer panels), 30% (20% and 60%), 80% (70% and 90%), and 25% (20% and 45%) of articles, respectively.

The results collected from trained and consumer panels have been compared in a few studies (Hutchings, de Casanove, et al., 2017; Rodrigues, de Souza, et al., 2016;

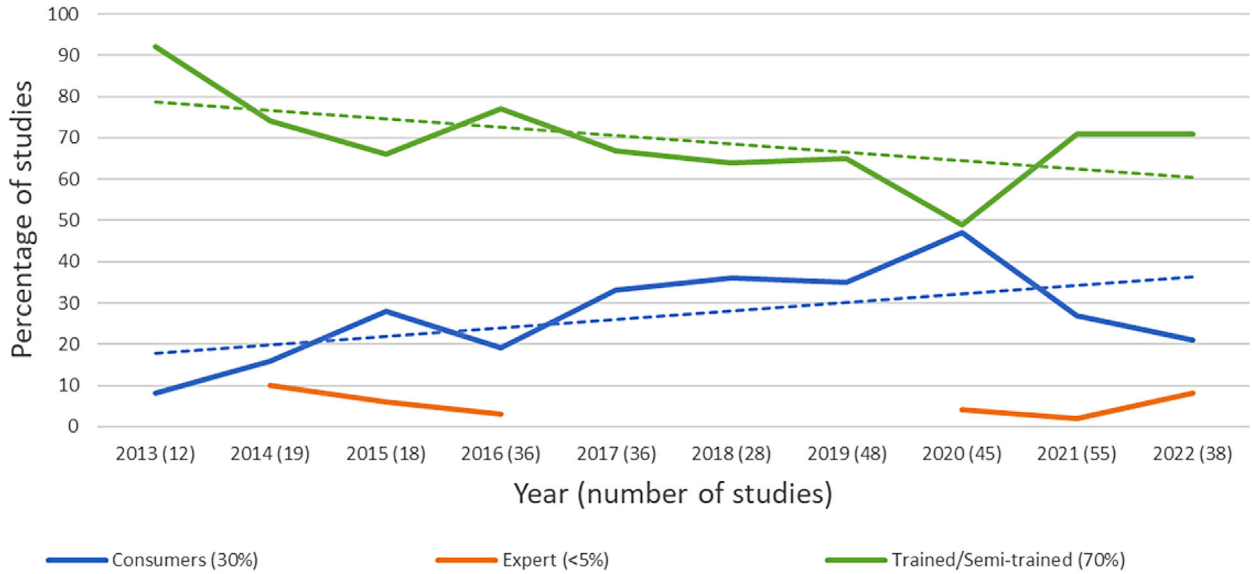

FIGURE 9 Types of panel involved in multi-attribute temporal descriptive measurements over the years, expressed as a percentage of the total number of studies published each year. An article can reference several studies involving different types of panels. Dashed lines represent the trend lines.

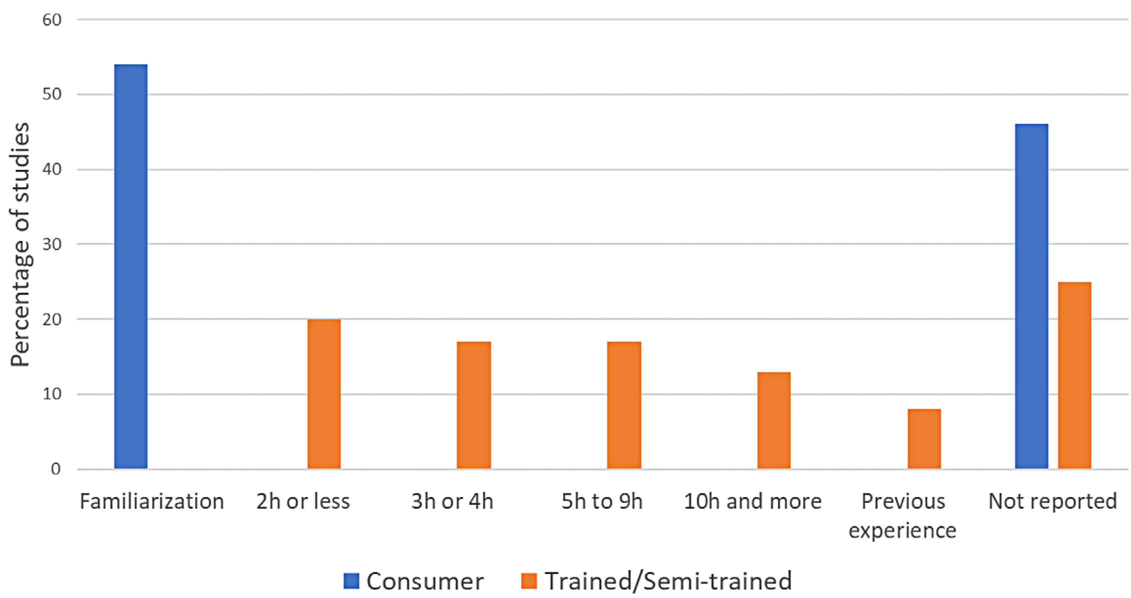

FIGURE 10 Details on training by type of panel.

Weerawarna et al., 2021). However, the conclusions seem to depend on the method and/or the product category under consideration.

These results suggest the need to deeper investigate the question of the subjects to formulate guidelines for the choice of the type of panel, the number of subjects they should include, the type and duration of training, and the way for reporting it. Meanwhile, it is important to explicitly report information about recruitment, selection modalities, training, demographics, and retribution of the subjects as well as settings of the experiment, all factors that have an impact in the repeatability of the test.

3.3.4 | Attributes choice and use

The following information on attributes were gathered: how were attributes selected for the study, the name of

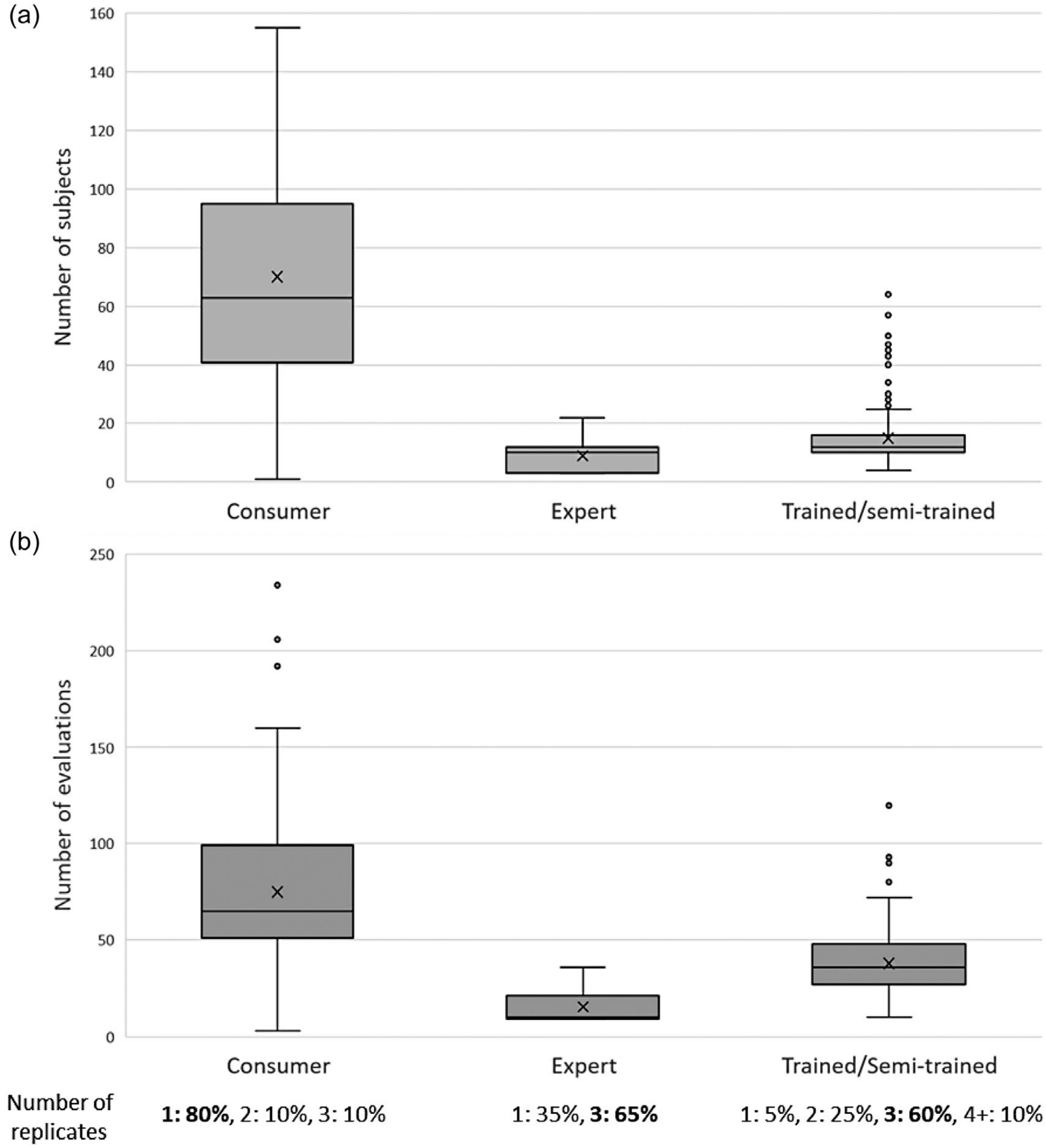

FIGURE 11 Distribution of the number of subjects and evaluations by type of panel: (a) number of subjects; (b) number of total evaluations (subjects by replicates). An article can reference several studies involving different numbers of subjects and evaluations.

the attributes, the sensory modalities represented, the total number of evaluated attributes, and their order of presentation. The presence of definitions and physical references was also registered, as these are also related to subjects training, results were already presented in Section 3.3.3 type of panel.

Figure 12a shows that most studies included 5–10 attributes, the mode being eight. This is in-line with classic recommendations about the number of attributes for TDS evaluations by Pineau et al. (2012).

Taking into account all the methods (Figure 12b), the most frequent observation was the use of attributes belonging to three sensory modalities by study: flavor, taste and texture (for solid products), or mouthfeel (liquid products). Most studies involving a single modality were dedicated to food oral processing research related to texture.

When analyzing the modalities evaluated, the most frequently proposed attributes correspond to basic tastes (sweet in 65% of articles, bitter in 50%, and sour and salty in 30%), then mouthfeel or texture attributes (astringent, soft, dry, creamy, hard, sticky, juicy, firm, metallic, melting, smooth, all between 10% and 25%). Flavor and aroma attributes are more specific and varied making it more difficult to group when analyzing all the papers.

Table 3 shows the most frequently used attributes in the main product categories. A large diversity is observed in the number of attributes by product category resulting also from the number of studies that evaluated the product

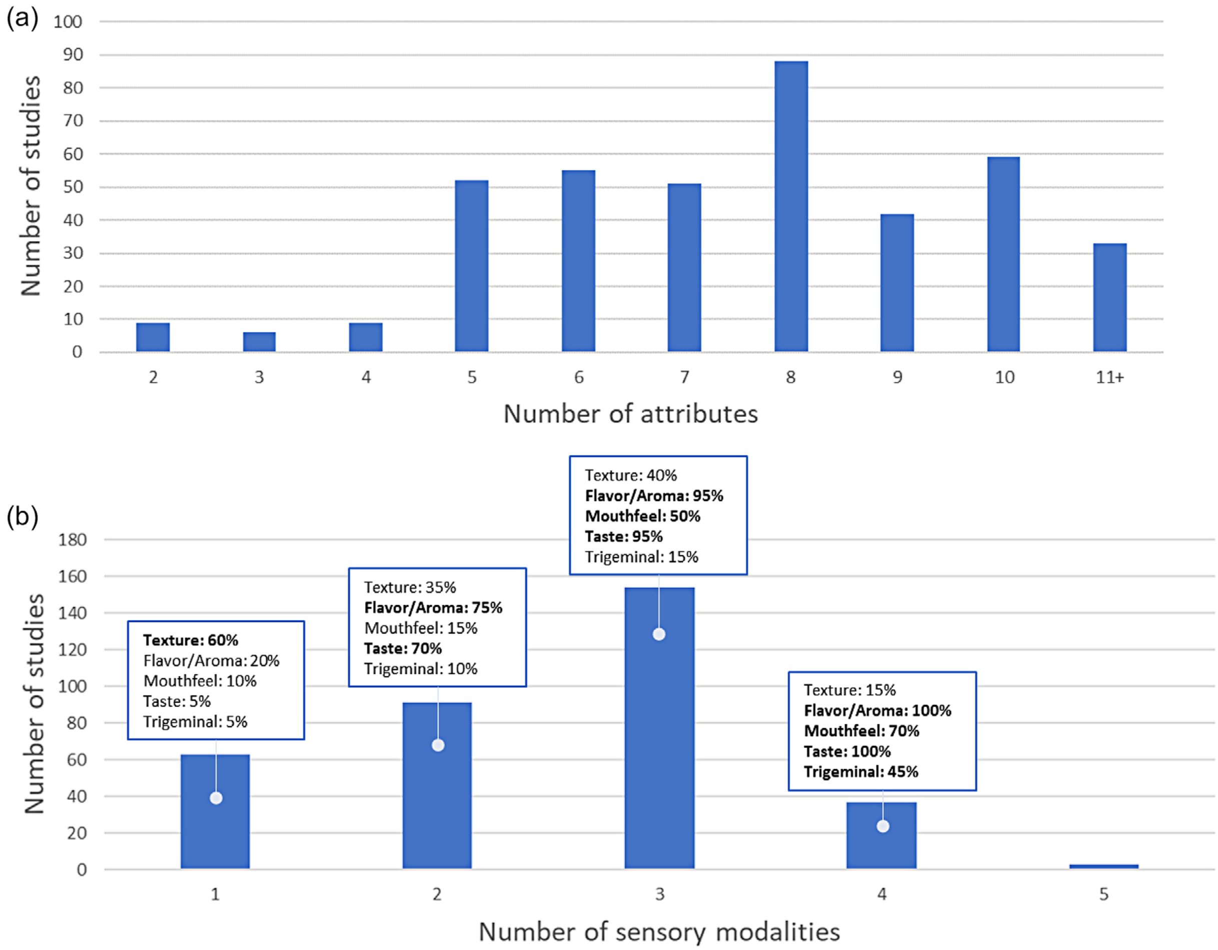

FIGURE 12 Use of attributes with temporal evaluation methods: (a) distribution of the number of attributes by study; (b) distribution of the number of sensory modalities by study. The % refers to the proportion of articles including this modality. An article can reference several studies involving different numbers of attributes and sensory modalities.

category; but it can give an overall idea of the complexity of the product categories. As noticed above, it has been recommended to limit the number of sensory attributes to keep the task feasible for subjects (up to 10 attributes for TDS—Pineau et al., 2012; up to 15 for TCATA—Jaeger et al., 2018). Thus, as explained in Section 3.2.2., for the most complex product categories (e.g., chocolates, cheeses, and wines), the selection of the attributes can be critical. This is why in some studies (very few) the authors added an attribute "other." An attribute "no taste" has also been added in approximately 10% of TDS studies, which amounts to allowing panelists to declare periods of non-dominance as with TDS-HD (see Table 2). Even though it represented a minority of the studies, some hedonic terms were also found as part of the descriptive list (e.g., "bad taste," Santos Gonçalves et al., 2017). Thus, as for subjects, it is important to explicitly report information about the basis for choosing the sensory attributes, and the presence (or absence) of definitions and references to subjects.

For studies involving trained and semi-trained panels, attributes were mostly (40%) chosen by the subjects conforming the panel. Other ways of selecting the attributes involved references from literature, choice done independently by the experimenter or by another panel (15% each). In 15% of the articles, the basis for the choice was not reported. The presentation order of the attributes was reported only in 45% of the articles. Within them it was found that: about 30% were randomized and 15% balanced (in accordance with the recommendations of Pineau et al., 2012 for TDS), and less than 5% fixed.

3.3.5 | Experimental design

To explore the uses of multi-attribute temporal methods in terms of experimental design, the following information was checked: the temporal unit (within intake, e.g., evaluation of changes in perception during a sip, or between intakes, e.g., evaluation of changes in perception over

TABLE 3 Attributes most frequently used (used at least twice) in main product categories (those evaluated in at least five articles) evaluated by multi-attribute temporal methods.

Product category	Main attributes[a]
Beers	Alcohol, astringent, bitter, carbonated citrus, chocolate, citric, coffee, estery, floral, fruity, full-body, grassy, herbal, honey, hoppy, lemon, malty, refreshing, sour, spicy, sweet, tingly, toasted, toffee, and warming
Biscuits	Buttery, crispy, crumbly, crunchy, dry, hard, and sticky
Breads	Aerated, bitter, butter, cardboard, bread, chewy, coarse, compact, crispy, crumbly, crunchy, dense, doughy, dry, fermented, grilled, hard, hydrated, metallic, off-flavor, roasted cereals, rough, salty, smooth, soft, sour, spongy, sticky, sweet, toasted, wet flour, and wheat
Cheeses	Semisolid: astringent, bitter, buttery, cheese, (cooked herbs), cream, creamy, crumbly, dry, firm, fresh (herbs), (garlic), gummy, grainy, off-flavor, peppery, pungent, salty, sharp, soft, sour, and spicy Hard: bitter, brittle, buttery, cheese, creamy, crumbly, dry, fatty, firm, fresh herbs, fruity, garlic, grainy, greasy, gummy, hard, melty, milky, mouth-coating, off-flavor, pungent, rancid, rubbery, salty, sharp, smooth, soft, sour, spicy, sticky, sweet, and thick
Chewing gums	Bitter, fresh, (mint), (peppermint), and sweet
Chocolates	Adhesive, astringent, bitter, brittle, buttery, caramel, chewy, chocolate, cocoa, coffee, creamy, crispy, crumbly, crunchy, dairy, dry, fruity, gooey, grainy, hard, melting, milky, mouth-coating, nutty, off-flavor, powdery, roasted, smooth, soft, sour, springy, sticky, sweet, vanilla, and woody
Coffee	Acidic, almond, astringent, bitter, burnt, caramel, chocolate, cocoa, coffee, fruity, herbaceous, nutty, roasted, sour, sugar cane, sweet, tobacco, and woody
Deli meats	Bitter, chewy, crunchy, cured, fatty, fibrous, firm, greasy, gummy, ham, hard, juicy, meat, off-flavor, pungent, rancid, salty, smoky, soft, spicy, succulent, tacky, tender, and umami
Milk desserts	(Caramel), cream, creamy, milky, off-flavor, soft, sweet, thick, and (vanilla)
Distilled beverages	Alcohol, burning, caramel, fruity, green, sweet, vanilla, and woody
Fruit juices	Acid, bitter, astringent, bitter, (grape), off-flavor, (orange), and sweet
Fruits	Astringent, bad taste, bitter, crunchy, fermented, fruity, hard, juicy, metallic, refreshing, soft, sour, sweet, and tasteless
Gels	Bitter, creamy, crumbly, elastic, grainy, melting, moist, refreshing, smooth, sticky, and sweet
Ice creams	Bitter, (cocoa), cold, creamy, icy, milky, roasted, sweet, and (vanilla)
Meats	Browned, dry, fatty, fibrous, firm, juicy, livery, meaty, oily, oxidized, smooth, soft, sweet, tender, though/hard, and umami
Milk beverages	Astringent, (cocoa), creamy, licorice, milky, mouth-coating, sweet, thick, and (vanilla)
Protein beverages and oral nutritional supplements	Astringent, bitter, (caramel), cardboard, (coffee milk), cooked, creamy, drying, filming, metallic, mouth-coating, (praline), salty, sweet, thick, and (vanilla)
Sausages	Chewy, dry, fatty, firm, grainy, hard, juicy, meaty, salty, slippery, smooth, soft, and spicy
Sweeteners	Bitter, chemical, drying, licorice, metallic, sour, and sweet
Vegetables	Adhesive, astringent, bitter, firm, juicy, pungent, salty, smooth, sweet, and vegetable
Wines	Acid, alcohol, adhesive, animal, apple, astringent, banana, bitter, black fruit, burnt, citrus, dark fruit, dry, drying, earthy, floral, fruity, grainy, green, grippy, heat, herbaceous, hot, mouthcoating, pineapple, puckery, pungent, red fruit, rose, smoky, sour, spicy, sweet, vegetal, woody, and yellow fruit
Yogurts	Acidic, artificial, astringent, bitter, (caramel), cloying, cold, cream, creamy, fatty, fermented, (lemon), licorice, melting, metallic, milky, off-flavor, sour, sticky, (strawberry), sweet, thick, thin, (vanilla), and viscous

Note: Attributes are presented in alphabetical order, not by modality.

[a]Between brackets: attributes depending on particular flavoring within the product category.

successive intakes), the duration of the tasting and the way in which it was standardized (e.g., free or fixed duration, free or fixed way of eating/drinking), and the product presentation order.

Figure 13 describes how the temporal descriptive tastings were implemented from a practical point of view. Most articles (85%) focused on the evolution of sensations within intakes, whereas 10% were interested also in the multi-intake approach and less than 5% focused only on the temporal description among intakes (Figure 13a).

Looking at those articles that evaluated the temporality within intakes, it was observed that the duration of the

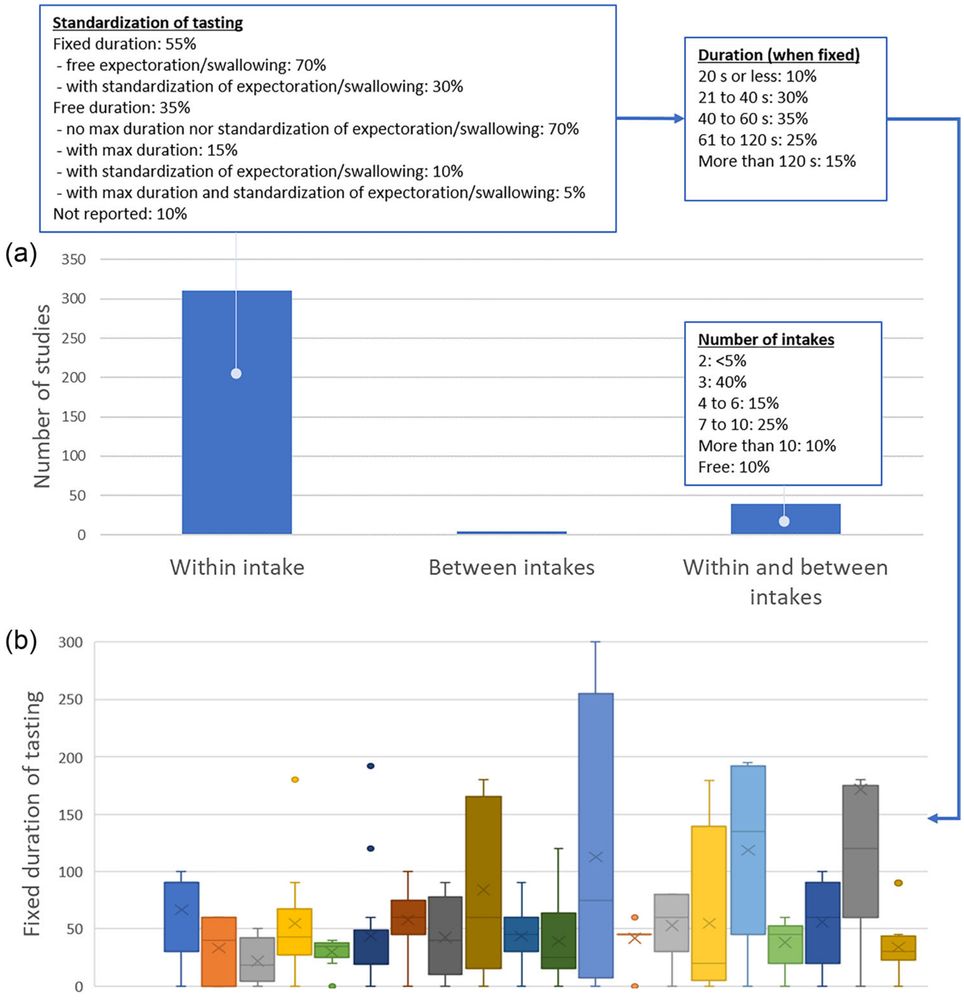

FIGURE 13 (a) Characterization of the tastings by temporal unit. (b) Distribution of durations of evaluation within-intake, for the main product categories (identified in Table 3).

tasting was free (remained to the choice of the subject) in 35% of studies. Among them, a maximum duration was imposed in 15%, and the moment to swallow or expectorate was standardized in 10%. The duration of the tasting was imposed (fixed) in 55% of studies, and among them 30% standardizing the moment of swallowing or expectoration. Deciding on a fixed or free duration of the intake can be determined by different factors, each having advantages and disadvantages. A free duration of the evaluation can be chosen, for example, when looking for a way of consumption closer to natural conditions. However, it will require certain posterior data transformation to unify temporal criteria among subjects. With a fixed duration, no posterior data treatment is necessary, but some information can be lost when choosing the duration. Even though this kind of choice are interesting and can have an impact on results, they were rarely explained or shared by researchers.

The fixed durations for the evaluations chosen by the researchers with an interest in the temporality within the intake, varied from very short (less than 20 s, 10% of studies) to more than six times that duration (more than 120 s, 15% of studies), but most durations (65%) were fixed between 21 and 60 s. Figure 13b shows that very different durations have been reported for products in the same category, notably with liquid ones. It is not possible to know whether these variations correspond to differences in duration between products of the same category or to differences in the implementation of the protocol. As with the descriptors, the choice of duration is critical, especially in TDS as the last descriptor selected is considered dominant up to the maximum duration chosen (in the absence of a STOP button).

Still considering articles that evaluated the temporality within intakes, the products were presented in a balanced or randomized order in 40% and 30% of the studies, respectively. The order was not reported in 30% of articles.

In real life settings, food products are rarely consumed on a single intake, but rather over multiple ones. This is why temporal methods also extend to study the evolution of sensory perception over consecutive intakes, looking for something more representative of natural eating behavior. SP (Table 2) was developed for this purpose, but almost all temporal methods have been used to characterize temporal dynamics of several intakes, even tough, as previously stated, this type of temporality interested only 15% of the studies. In these studies, the number of evaluation ranges between 2 and 30, the mode being 3 (40% of studies, Figure 13a).

Table 4 presents the details of implementation of temporal methods with products evaluated over successive intakes. Most studies focused on liquid products presenting bitter or astringent compounds known to have a build-up sensation. Overall, the implementations vary largely within and between product categories, in the number of intakes, the duration of evaluation of intakes and in the quantity of product consumed. In about 40% of articles only three intakes were evaluated (Figure 13a), probably for practical reasons especially when working with alcoholic beverages. In this case, the tasting can hardly be considered a representative of full product consumption. As it is plausible that a minimum quantity is necessary to observe built-up effects, it could explain why some articles (Table 4) did not conclude on the multi-intake measurements.

3.3.6 | Data acquisition software

Some methods are more used in certain geographic regions or with certain software (comparatively to the relative use of methods), notably TDS with SensoMaker and TimeSens, and TCATA with CompuSense. These results can probably be explained by the geographic proximity between the software distributors and their customer base. They also suggest an influence of the software on the use of the methods, either indirect (availability or nonavailability of the method in the software) or direct (promotion of methods by software distributors). This can be explained by the academic competition between the few teams (including that of the first author of this review) involved in methodological and/or software development. Indeed, among the 1027 different contributors to the articles included in this review, 25% of the 363 articles were coauthored by three researchers who are directly or indirectly involved in the development or promotion of a software (TimeSens, CompuSense, or SensoMaker). This entanglement between software and methods can add a bias to the choice of temporal methods in research and the conclusions reached in methodological articles (see Section 3.5).

3.4 | Analysis of temporal sensory data

To have an overview of how multi-attribute temporal sensory data was analyzed in the literature, the following information was registered: If data were transformed and how, which were the variables and statistical analyses used, if there were inferential statistics and values for alpha determined beforehand, and the software used for data analyses.

3.4.1 | Main variables and data transformations

Figure 4 previously shows that temporal methods have evolved from the use of quantitative intensity scales to a qualitative evaluation. It seems that the methodologists constantly seek to find the best compromise between the level of detail of the data collected and the difficulty of the evaluation task for the panelists (e.g., intensity for one attribute with TI, then intensity for several attributes with DATI/MATI, then intensity for the dominant attribute with TDS-I, then only dominance, then applicability for several attributes with TCATA, then applicability with no need for uncheck with TCATA-F, and then applicability per period with AEF-A).

Figure 14 shows what the collected data look like and how they are possibly transformed. With intensity-based methods such as TI and PP (but also DATI, SP, or MATI), all presented attributes are rated at any given time on linear scales derived from classical DA (presented on an *x*–*y* plan in DATI). Only TI and DATI data are continuous, panelists having to move the cursor constantly. For other methods, data are fixed interval data (times of evaluation are imposed). Data are directly stored as *attribute x time* matrices of intensity scores (one by *product* × *subject*). The same goes for retrospective methods such as AEF-A (but also FC-AEF-A, AEF-D, Quessence, and F-TOS), replacing intensity scores by 1 or 0 standing for presence or absence (0: not dominant/applicable and 1: dominant/applicable). For TDS and TCATA, it is quite different as data collection relies on stochastic processes (non-fixed interval data, times of evaluation are chosen by the panelists). Collected data consist in an ordered sequence of events constituted of two several random variables: the selected attribute (dominant/applicable attribute), the time of click on the attribute, and the value corresponding to the state of the attribute (0/1 for dominant/applicable attributes, intensity of the dominant attribute with TDS-I). For the purpose of data representation and statistical analysis (see Section 3.4.2), these events are transformed in discrete time series assumed as continuous if the discretization step is small

TABLE 4 Details of implementation of temporal methods with products evaluated over successive intakes (categories of products evaluated at least in three articles).

Product category	Method	Type of panel	Temporal unit[a]	Number of intakes	Total quantity	Duration by intake	Reference	Conclusion related to evolution of product description over multiple intakes (as reported in abstract)
Beers	AEF-A D-TCATA	C	WB	7	Free	Free	Visalli et al. (2022)	No difference in perception over intakes
Beers	SP	T	B	5	Free	NA	Vázquez-Araújo et al. (2013)	–
Beers	M-TCATA	T	WB	2	40 mL	90 s	Dietz, Cook et al. (2022)	Limited effects were observed between sips
Beers	TDS	C	WB	6	120 mL	50 or 90 s	Corrêa Simioni et al. (2018)	Increased dominance of bitterness, decreased dominance of fruity, floral, toffee, and coffee
Beers	TDS	C	WB	Free	80 mL	Free	Silva et al. (2019)	–
Beers	TDS	E; C	WB	Min 3	E: 350 mL C: 500 mL	30 s	Wakihira et al. (2020)	Fewer built-up effects with less standout flavor beers
Beers	TDS	C	WB	15	330 mL	Free	Machado et al. (2023)	Duration of perception gradually decreased
Protein beverages/ONS	SP	T	WB	8	40 mL	60 s	Methven et al. (2010)	Built-up of mouthdrying, mouthcoating, metallic, and soya
Protein beverages/ONS	SP	T	WB	30	600 mL	90 s	den Boer et al. (2019)	Mouthdrying first increased, up to a consumption volume of 300 mL, and then decreased
Protein beverages/ONS	SP	T	WB	8	40 mL	20 s	Withers et al. (2014)	Built-up of mouthdrying
Protein beverages/ONS	SP	T	B	8	120 mL	NA	Lester et al. (2021)	Built-up of mouthdrying and higher aftertaste perception
Protein beverages/ONS	SP	T	WB	8	40 mL	60 s	Bull et al. (2017)	Built-up of mouthcoating, drying, and chalky
Protein beverages/ONS	TDS	C	WB	Free	Free	Free	Thomas et al. (2016)	–

(Continues)

TABLE 4 (Continued)

Product category	Method	Type of panel	Temporal unit[a]	Number of intakes	Total quantity	Duration by intake	Reference	Conclusion related to evolution of product description over multiple intakes (as reported in abstract)
Protein beverages/ONS	TDS	C	WB	10	Free	Free	Thomas et al. (2018)	–
Protein beverages/ONS	TDS-I	T	WB	3	120 mL	Free	Cosson et al. (2020)	Built-up of fatty, decrease of beany and bitter
Wines	DA	E	B	7 over 30 min	50 mL	NA	Lytra et al. (2016)	Evolution of fruity notes
Wines	SP	T	WB	4	20 mL	60 s	Olatujoye et al. (2020)	Built-up of astringency
Wines	TDS	C	WB	Free	80 mL	Free	Silva et al. (2018)	–
Wines	TDS-D	T	WB	3	30 mL	90 s	Pittari et al. (2022)	–
Wines	TDS	C	WB	3	30 mL	Free	Galmarini et al. (2017)	–
Yogurts	M-TDS	T	WB	3	40 mL	30 s	Lesme et al. (2020)	Global flavor perception of the samples varied with the number of spoons, which particularly impacted the taste attributes
Yogurts	SP	T	B	2	Two or four spoons	NA	Palczak et al. (2020)	–
Yogurts	TDS	T	WB	3	15 g	20 s	Souza Olegario et al. (2022)	Numbers of intakes presented a significant impact on temporal perception
Yogurts	TDS	C	WB	5	60 g	Free	van Bommel, Stieger, Boelee et al. (2019)	Built-up of dominance for sticky
Yogurts	TDS	T	WB	3	50 g	45 s	Chadha et al. (2022)	Increased dominance of bitter and astringent

Abbreviations: AEF-A, attack-evolution-finish with applicability; DA, descriptive analysis; D-TCATA, discrete time TCATA; M-TCATA, TCATA by modality; M-TDS, TDS by modality; SP, sequential profile; T, trained/semi-trained, C: consumers; TDS, temporal dominant of sensations; TDS-I, temporal dominance of sensations with intensity.

[a]WB: evaluation within intakes and between intakes, B: evaluation only between intakes.

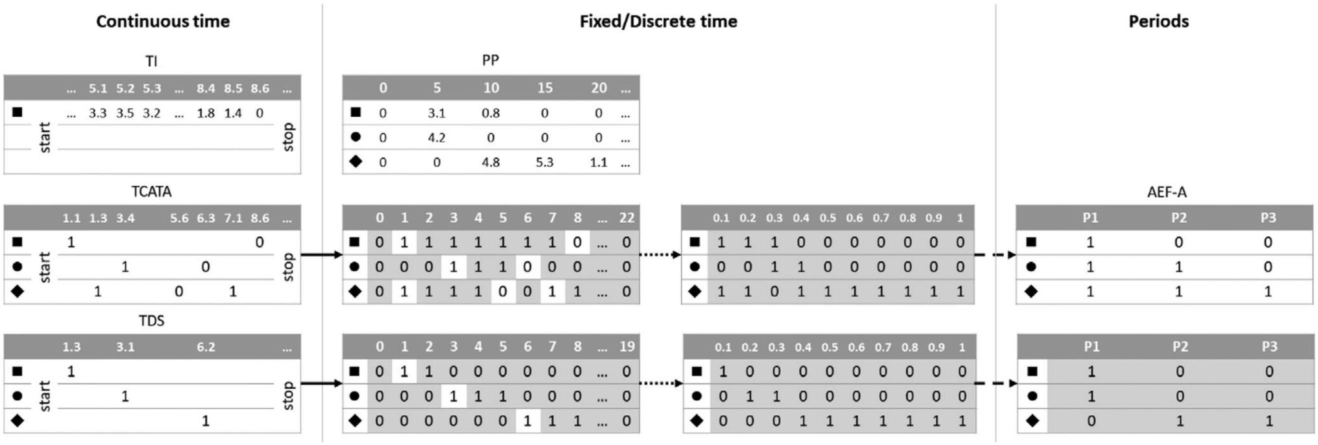

FIGURE 14 Examples of data collected at continuous times (intensity, dominance, and applicability), fixed predetermined moments of consumption (progressive profile), and recapitulative time periods. Plain arrows represent discretization; dotted arrows are for time standardization; and dashed arrows for transformation in periods. Gray cells: imputed data. Different symbols represent sensory attributes.

enough. Some variable transformations are justified by the intrinsic complexity of dynamic methods, which add a new source of uncontrolled variability in data. To disregard subjects' temporal signatures or heterogeneity in times to first citations (Tfirst) and total durations (Dtot), temporal data can be standardized by subject (Lenfant et al., 2009), that is, transformed between 0 (corresponding to Tfirst of the subject) and 1 (corresponding to Dtot of the subject). Time standardization is relatively frequent in TDS (40% of studies, 75% when no time limit is imposed in the protocol), less in TCATA (20% and 40%).

Other treatments are probably related to the scientific community's greater predilection for tests with parametric and quantitative analyses. For example, the division of time into periods (between 3 and 20, being 3 or 4 periods the most frequent) is used in 10% of TDS studies and 20% of TCATA. It is to be noted that the transformation of TCATA and TDS in periods makes the structure of data similar to those of AEF-A, and for TDS several dominant attributes can be cited within a given period.

Table 5 shows the main variables related to data collected with temporal methods. Among these 31 variables, only 9 are primary (those suffixed with the letter in Table 5), that is to say that they were directly collected and can be observed in data matrices (see Figure 14). These primary variables are rarely analyzed as such, but other variables are derived from them using computations either at the subject or panel level. For example, in TDS, durations are not directly asked to the panelists but computed as the difference between two successive citations of distinct attributes. At the panel level, only citation rates (CR_t) and mean intensities ($IMEAN_t$) are computed at each time. These two variables have been used in more than 90% of the articles. The variables aggregated by period require prior data transformation (Figure 14) that necessarily results in a loss of TR. The aggregation at global level is an inheritance of TI curves parameters (e.g., AUC, TMAX, DMAX, RINC, RDEC, and IMAX/CRMAX, see Table 5).

Figure 14 and Table 5 show that what is analyzed is different from what is actually collected during product evaluation. The primary variables undergo many transformations and/or aggregation, sometimes unnecessary and/or excessively manipulating the nature of the data, with an unclear impact on results. Time standardization distorts individual sequences (Meyners, 2020) while there is no consensual evidence on the beneficial effects of this transformation. For TDS, it has been shown that time standardization complemented analysis on raw data (Lesme et al., 2020) or highlighted most differences between products (Frost et al., 2018). For TCATA, the opposite effect was observed (Dietz, Yang, et al., 2022). For transformation into periods, the choice of the number and duration of periods was almost always arbitrary, except for Lecuelle et al. (2018) who automatically determined them. If this transformation simplifies data analysis, it is however unlikely that periods should be chosen of uniform sizes, and the choice can have an impact on conclusions (Beaton & Meyners, 2020).

3.4.2 | Main statistical analyses

Table 6 shows that numerous statistical analyses (more than 100 were found, only those used more than once are presented) have been used for gaining insights about temporal data. The data analyses have been classified into two categories: exploratory (including techniques used to investigate the data and summarize the main characteristics of the dataset) and confirmatory (including techniques based on statistical inference or parametric and

TABLE 5 Main variables (used at least in two articles) derived from data collected with temporal methods and the abbreviations used in the present article for each by time period and globally.

Variable	By time	By period	Global
Variable collected or computed at the subject level with intensity-based methods			
Intensity, by attribute[a]	I_t	I_p	–
Mean intensity, by attribute	–	Imean_p	Imean
Max intensity, by attribute	–	Imax_p	Imax
TDS score, by attribute (duration std/no std × intensity)[a]	–	DI_p	DI
Duration of perception (intensity >0), by attribute[a]	–	D_p	D
Variable collected or computed at the subject level with qualitative methods			
Citations, by attribute[a] (dominant/applicable = 1, not dominant/not applicable = 0)	C_t	C_p	C
Rank of citation, by attribute[a]	RC_t	–	RC
Time to first citation[a]	–	–	Tfirst
Time or period to first citation, by attribute[a]	–	–	T
Citation, after period or static transformation, by attribute	–	C_p	C
Number of citations, by attribute	–	N_p	N
Duration (std/no std) of applicability/dominance, by attribute	–	D_p	D
Sojourn time (std/no std) of applicability/dominance, by attribute	–	S_p	S
Number of attributes cited	–	Natt_p	Natt
Number of citations	–	Ncit_p	Ncit
Variable collected[a] or computed at the subject level common to intensity-based and qualitative methods			
Total duration of perception[a]	–	–	Dtot
Number of intakes[a] (if applicable, see Implementation)	–	–	Nint
Variable computed at the panel level with intensity-based methods			
Mean intensity, by attribute (mean of Imean)	IMEAN_t	IMEAN_p	IMEAN
Max intensity, by attribute (max of IMEAN)	–	IMAX_p	IMAX
Variable computed at the panel level with qualitative methods			
Citation rate (or frequency), by attribute	CR_t	CR_p	CR
Mean citation rate, by attribute	–	CRMEAN_p	CRMEAN
Max citation rate, by attribute	–	CRMAX_p	CRMAX
Duration above significance (TDS), by attribute	–	DSIG_p	DSIG
Variable computed at the panel level common to intensity-based and qualitative methods			
Mean duration, by attribute (mean of D)	–	DMEAN_p	DMEAN
Mean sojourn time, by attribute (mean of S)	–	SMEAN_p	SMEAN
Number of transitions from one attribute to another, by attribute	–	TR_p	TR
Area under the curve (CR_t or IMEAN_t), by attribute	–	AUC_p	AUC
Time to CRMAX or IMAX, by attribute	–	TMAX_p	TMAX
Duration above 90% of CRMAX or IMAX, by attribute	–	DMAX_p	DMAX
Rate of increase, by attribute	–	RINC_p	RINC
Rate of decrease, by attribute	–	RDEC_p	RDEC

Abbreviation: std, time standardization.
[a]Collected variables.

nonparametric tests to decide whether or not the data support a particular hypothesis). Regarding the assessment of global differences between products, the most used analyses were univariate linear models such as ANOVAs (20% of the articles) or multivariate maps such as PCA (10%) or CVA (10%). These analyses were derived from those generally applied with static DA methods and applied on citation rates, durations, or intensities aggregated by period or as area under curves, thus ignoring the dynamic dimension in the data. "Trajectory maps" (mostly CA and PCA) were

TABLE 6 Main statistical analyses reported in the literature (cited at least twice) grouped by category.

Method category	Exploratory and confirmatory data analysis methods	Variables[a]	Number of articles[b]	Selection of references[c]
Checking for subjects' behavior and performance				
Qualitative	Linear models[d] (ANOVAs, *t*-tests, etc.) for comparison of subjects' behavior	Tfirst, Dtot, Natt, Ncit	19/333	–
Qualitative	Repeatability/agreement index	C, C_t	5/333	Castura, et al. (2016), Dietz, Yang et al. (2022), Fiches et al. (2016), Hutchings, Foster, Hedderley et al. (2014), Poveromo and Hopfer (2019)
All	Linear models[d] for assessment of performances	I, D, C, CR, CR_p, RC, index	22/363	Dietz, Cook, et al., 2022, Dinnella et al. (2012), Hutchings, Foster, Grigor, et al. 2014, Hutchings, de Casanove et al. 2017, Keefer, et al. 2022, Kuesten et al. (2013), Lepage et al. (2014), Mesurolle et al. (2013), Nguyen et al. (2018); Palczak et al. (2019), Visalli et al. (2016)
Qualitative	Plot of citation rates by subject or plot of differences[d] in citation rates over times to assess panelist or panel repeatability	CR_t	4/333	Patterson et al. (2021), Visalli et al. (2016), Young et al. (2013)
Qualitative	Randomization tests[d] for assessment of performances	–	2/333	Meyners and Castura (2018), Meyners (2011)
Assessment of temporal evolution within product				
Dominanc	Plot of citation rates over time/period, with comparison to chance, by subject or attribute	CR_t, CR_p	241/282	Missbach et al. (2017), Pineau et al. (2009); Visalli et al. (2020)
TDS	TDS bandplots	CR_t	24/281	Galmarini et al. (2017)
TDS	Graph of transitions	TR, TR_p	3/281	Castura (2020), Lecuelle et al. (2018)
Assessment of global differences between products (not based on temporal evolution)				
All	PCA	CRMEAN, CRMAX, DMEAN, AUC, IMAX, IMEAN, DI, TMAX, DMAX	33/363	–
Qualitative	CA	CR	6/333	–
Qualitative	Canonical/conditional CA	CR	3/333	Beaton and Meyners (2020)
All	Linear models[d]	D, CR, C, I, AUC, AUC-Sig, RDEC, RINC, T, IMAX, DI, TMAX, CRMAX, CRMEAN, RC, and Tfirst Dtot, Natt, Ncit	75/363	–

(Continues)

TABLE 6 (Continued)

Method category	Exploratory and confirmatory data analysis methods	Variables[a]	Number of articles[b]	Selection of references[c]
All	Nonparametric tests[d] (Cochran *Q*-test, Friedman test)	CR, D, I	7/363	–
Qualitative	Bootstrap tests[d]	CR	2/333	Okamoto (2021), Shimaoka et al. (2022)
All	PARAFAC	CR	2/363	Rodrigues, Condino et al. (2016)
All	PLS-R	CR, *I*	4/363	Kang et al. (2020); Pu et al. (2019)
All	MANOVA[d]/CVA[d]	D, DI, I, DMAX, TMAX, CRMAX, CRMEAN	36/363	Galmarini et al. (2016)
Intensity	MAM-CVA[d]	I	2/39	Kang et al. (2019)
TDS	Semi-markov models[d]	S, TR, TR_p	3/281	Cardot et al. (2019), Frascolla et al. (2022); Kurata et al. (2022), Lecuelle et al. (2018)
Qualitative	Randomization tests[d]	–	3/233	Meyners (2020), Meyners and Castura (2019), Meyners and Pineau (2010)
Qualitative	mrCA[d] + hypergeometric test	CR	3/233	Mahieu et al. (2020)
All	PCA[d] with partial/total truncated bootstrap[d]	CR_t	2/333	Castura et al. (2022)
Assessment of temporal differences between products				
Qualitative	Plot of citation rates over time, with comparison to all other products	CR_t	56/333	Castura, Antunez, et al. (2016), Dietz, Yang, et al. (2022)
All	Trajectory PCA by period	$IMEAN_p$, $CRMEAN_p$, $DMEAN_p$	40/363	Galmarini et al. (2016), Lenfant et al. (2009)
Qualitative	Trajectory CA/MRCA by period	CR_p	13/333	Castura, Antunez, et al. (2016), Visalli et al. (2020)
All	Linear models by period[d]	D_p, $CRMEAN_p$, C_p, I_p, $CRMAX_p$	15/363	–
Qualitative	Plot of differences in citation rates over times[d]	CR_t	69/333	Castura, Antunez et al. (2016), Pineau et al. (2009)
Intensity	Intensity curves	I_t	9/39	Kuesten et al. (2013), Methven et al. (2010), Zimoch and Findlay (1998)
Clustering				
All	HCA	Coordinates of PCA	5/363	Lorido et al. (2018)

[a]See Table 5 for abbreviations.
[b]Number of articles: actual use/potential use.
[c]References are reported only for analysis specifically developed or adapted for temporal sensory data.
[d]Confirmatory data analysis.

also used to represent the evolution of variables by period (15%).

With intensity-based methods, there was a prevalence of parametric procedures in the analysis of results. For TDS and TCATA, the most used analyses (more than 80% of articles) were the plots of citation rates over time. These plots can be used to assess the temporal evolution of the agreement among panelists regarding the dominance or applicability of a specific attribute. TDS proposes determining the significantly dominant attributes within a product based on the comparison of citation rates of attributes in relation to a significance threshold. As this test does not allow statistical comparisons between products or attributes to be made, it was considered an exploratory analysis. For TCATA, there is no such significance threshold, and the significantly applicable attributes within a product are determined by comparison to all other products (as with difference plots). Difference plots of citation rates over time were used in about 20% or the articles. For intensity-based methods, plots of intensity over time were used in 20% of the articles. All other analyses were used in less than 10% of the articles, probably because they are not available in main commercial software.

These results denote that—except for the plots of citation rates/intensity over time—there is little agreement on the "must do" analyses. As with data acquisition software (and probably even more) it is likely that the choice of the data analysis depends on its availability and its easiness of use. As a result, primary variables were rarely analyzed as such, thus very few articles considered individual differences in temporal perception. Likewise, few articles had statistical analysis related to subjects' behavior or panel performance. Half of the articles based their conclusions exclusively on exploratory data analyses (e.g., visual inspection of curves), inappropriate to draw robust conclusions on product comparisons (Meyners, 2020) and submitted to subjective interpretations. The other half used confirmatory data analyses enabling an objective interpretation based on a statistical criterion. Among them, 20% considered the sequentiality of perceptions (see Table 6, assessments of temporal differences between products confirmatory analysis are suffixed by a star), the main interest of temporal measurements. About 40% of articles reported the alpha risk in the data analysis section prior to present results, and almost none mentioned the size effect. The way of reporting statistical results on multi-attribute temporal methods should evolve to follow recent recommendations on better practices (Aguinis et al., 2021; Johnson et al., 2020).

3.5 | Comparison of methods

Comparison between methods was done in 15% of the articles (for 55% of them comparison was a primary objective while for the other 45% it was secondary). To evaluate how the comparisons were carried out, seven criteria were considered (taking into account what was presented more often in the concerned papers): the overall differences ("Different"), similarities ("Similarity"), or complementarities ("Complementary") between methods (reported or not), plus conclusion ("+" or "−") about which method is "better" regarding their capacity to highlight temporal patterns within product ("Temporal"), to give complete description of products ("Description"), to discriminate between products ("Discrimination"), and to give consensual results at the panel level ("Agreement"). The criteria were evaluated based on the conclusions reported by the authors. Example: "TDS and TCATA provided *comparable information* for the key sensory attributes characterizing and differentiating the regular and sodium-reduced products. TDS was *more discriminative* than TCATA for single-product intakes, while TCATA generated *more consistent* profiles across multiple intakes." (from Nguyen & Wismer, 2022) was summarized as "TCATA-F versus TDS: Similar, Discrimination−, Agreement+."

Table 7 shows that most method comparisons involved TDS/TDS-I versus DA, TDS versus TI, and TCATA versus TDS. TDS and TDS-I were declared complementary to DA in about two articles out of three stating that TDS add a temporal dimension (something that could be expected without carrying out any experiment, given the nature of the methods). Similarities were also reported between TDS-I and DA in the same proportion (probably linked to the fact that both are descriptive methods). No clear conclusions emerged from comparisons between TDS and TI. TDS and TCATA were judged as complementary in about one article out of two, whereas one article over three said that TCATA provided a better product description. Among all the articles comparing methods, "negative" findings (e.g., less discrimination/information or unexplained differences) concerning the more recent method have been reported in less than 20% of articles, which could be symptomatic of a publication bias (Nair, 2019).

This qualitative assessment is probably reductive because it relates to the main conclusions reported by the authors in the abstracts. Indeed, a lot of different criteria have been used in the articles to compare the temporal methods, and regarding the diversity of the statistical analyses performed, it was not possible to rely on specific outputs that would have enabled a more generic characterization. Moreover, only 2/3 of conclusions were supported by confirmatory analyses and 1/3 by confirmatory data analyses considering sequentiality of perceptions (larger proportions than in Section 3.5). Thus, these results have to be considered general trends rather than definitive conclusions, especially considering that some concepts related to temporal measurements might be beyond comparison (Meyners, 2020). However, this highlights the need for guidelines and methodology to compare results collected in different studies with different methods. In particular, it was observed that only 10% of the articles including method comparisons reported some results about reliability and/or validity. Most methodological conclusions were based on the capacity of methods to discriminate between products. However, statistical significance is not necessarily a synonym of meaningful results nor of validity (Stone et al., 2012). Such face validity is considered the weakest form of validity, at risk for research bias when people subsequently conclude based on low evidence. Discrimination should not be considered the golden rule to validate methods,

TABLE 7 Main conclusions reported in articles involving method comparisons (one article can include multiple comparisons).

Method 1*	Method 2*	Number of studies	Different	Similar	Complementary	Temporal[a]	Description[a]	Discrimination[a]	Agreement[a]
AEF-A	**D-TCATA**	1		1				+: 1	
AEF-D	**TDS**	1		1					
DATI	**TI**	2					+: 2	+: 1	
M-TDS	**TDS**	2		2			+: 1	+: 2	−: 1; +: 1
PP	**DA**	1		1	1	+: 1			
PP	**TI**	2		1	1		−: 1		
TCATA	**CATA**	2		2	1	+: 1			
TCATA	**DA**	1		1					
TCATA	**PP**	1		1			+: 1		
TCATA	**TDS**	11		6	2	−: 1	+: 4	−: 1; +: 2	
T-CATA	**M-TDS**	1		1			+: 1	+: 1	
TCATA-F	**TCATA**	3		1			+: 1	+: 2	+: 1
TCATA-F	**TDS**	1		1				–	+: 1
TDS	**CATA**	1	1						
TDS	**DA**	11	2	1	8	+: 6	−: 1; +: 1	+: 1	
TDS	**PP**	2		1	1		+: 1		
TDS	**TI**	9	1	1	3			+: 1	
TDS-HD	**TDS**	1		1					
TDS-I	**DA**	10	1	6	6	+: 7	−: 1; +: 1	+: 1	
TDS-I	**PP**	1		1	1				
TDS-I	**TI**	2		2			+: 2		
TR	**TCATA**	1		1				+: 1	

Abbreviations: AEF-A, attack-evolution-finish with applicability; AEF-D, attack-evolution-finish with dominance; CATA, check all that apply; DA, descriptive analysis; DATI, dual-attribute time–intensity; D-TCATA, discrete time TCATA; M-TDS, TDS by modality; PP, progressive profile; TCATA, temporal check all that apply; TCATA-F, TCATA fading; TDS, temporal dominant of sensations; TDS-HD, TDS hold down; TDS-I, temporal dominance of sensations with intensity; TI, time–intensity; TR, temporal ranking.

[a]Temporal/Description/Discrimination/Agreement: number of articles concluding in superiority (+) or inferiority (−) of Method 1 compared to Method 2 regarding the capacity to highlight temporal patterns within product, to obtain complete descriptions of the products, to discriminate between different products, to reach high agreement between subjects, respectively.

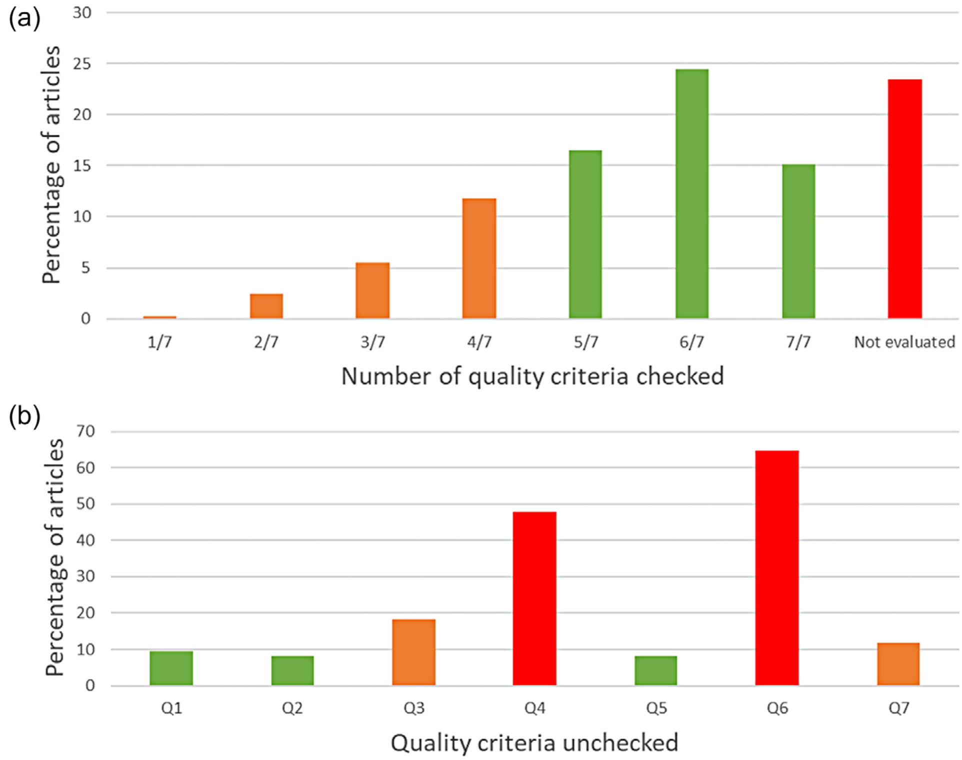

FIGURE 15 Quality appraisal of the included articles. (a) Distribution of the quality scores of articles (green: good or acceptable quality, yellow and orange: passable or poor quality). (b) Distribution of the percentage of articles having quality criteria unchecked, by criteria (green: less than 10%, orange: between 10% and 30%, red: above 30%, Q1: "Clear research question?", Q2: "Appropriate participants?", Q3: "Appropriate design and data collection?", Q4: "Appropriate data analysis?", Q5: "Claims supported by evidences?", Q6: "Integrated interpretation and conclusion?", and Q7: "Useful contribution?"). *Note*: The authors were involved (directly or not) in 45 articles which were also evaluated.

validity (even if it is difficult to establish), and reliability matter (see Moskowitz, 2008 for an old but still actual debate).

3.6 | Dissemination of research involving temporal sensory evaluation methods

3.6.1 | Quality appraisal

Figure 15a shows the result of the quality appraisal (see Section 2.1.3) of the included articles. About 25% of the articles were not evaluated, mostly because there was no reference to a temporal evaluation method in the introduction. This result was quite surprising because temporal evaluation methods are not routinely used and even if they are used as a secondary measurement their choice is generally guided by specific hypotheses. For the other articles, the mean quality score was 5.3/7: overall, 15% have the maximum score, 55% have a score greater than 4, a little less than 10% a score lower than 4. The least validated criteria were Q6 ("Integrated interpretation and conclusion?", 65% of articles not validating the criterion) and Q4 ("Appropriate data analysis?", 45%).

For Q6, it can be noticed that no limitations were reported in 60% of the evaluated articles, and for Q4 the high percentage of non-validated articles is explained by conclusions exclusively based on subjective qualitative analyses in 40% of articles. Other reasons include not reporting product and/or attribute presentation orders (Q3, 10%) and not reporting contributions to the field (Q7, 10%). These results and those reported in previous sections demonstrate a lack of standards (or their application) for reporting and reviewing research related to multi-attribute temporal sensory evaluation methods and probably other sensory measurements as well. This issue is not specific to food science (Sizo et al., 2019), but questions the perception of the quality in research (see Akdag, 2019 for a discussion).

Some basic advices can be drawn from these results. When using temporal evaluation methods for research purposes, it is recommended to justify the choice of methods supported by adequate references with regards to the hypotheses and the objective of the research (these hypotheses/objectives should be clearly stated in the introduction, see Thomas & Hodges, 2010 for recommendations). If new methods or variants are introduced, extensive bibliographic research should be done to avoid "reinventing" an existing method. An appropriate use of both exploratory and confirmatory analysis should be made to draw more robust conclusions (see Fife & Rodgers, 2021 for a substantiated argument). Every research has limitations, and reporting them is a guarantee of quality and rigor in research, ensuring readers do not overemphasize or minimize findings (Ross & Bibler Zaidi, 2019). As noticed in section 3.3.1, when sensory evaluation is a secondary measurement and the author does not have expertise in the field of sensory science or data analysis, appropriate coauthors should be associated to the research work. To help researchers to report their works and reviewers to evaluate the completion of submitted articles, we propose a checklist derived from the criteria used to evaluate the articles in this review (Visalli & Galmarini, 2022). This checklist (Visallli & Galmarini, 2023) is versioned and can be downloaded on a public repository from this URL: https://doi.org/10.57745/JUJRTJ.

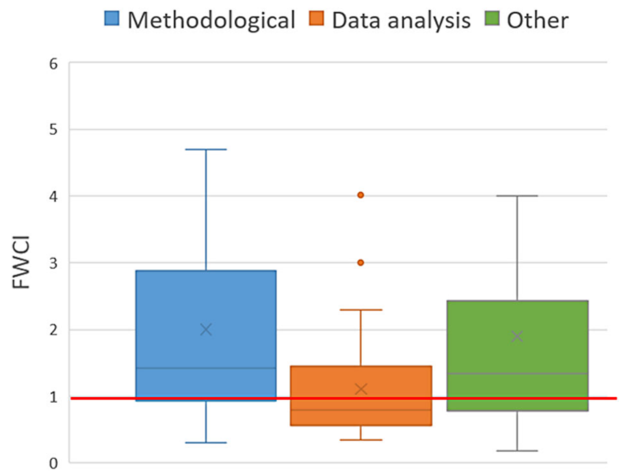

FIGURE 16 Field-weighted citation impact (FWCI) of articles by area of knowledge.

3.6.2 | Compliance to ethics in research and open science

About 40% of articles were published in open access, with a clear increasing trend. More than 50% have been published in open access over the last two years, against less than 30% 10 years ago. This percentage is rather fair compared to other disciplines (Demeter et al., 2021).

Over the last two years, 90% of published articles included funding sources and declarations of interest, 70% authors' contributions, 60% subjects' informed consent, and 45% a review board approval (or exemption). However, less than 1% of research data are available on public repository and meet the principles of findability, accessibility, interoperability, and reusability (FAIR). This low percentage can be explained by a lack of familiarity with the FAIR principles (Brock, 2019) or by reluctance to share data on commercial products. As a second step toward FAIRification of data (Visalli et al., 2023), we propose a template for sharing data and metadata related to sensory evaluation measurements. This template (Visalli & Galmarini, 2023) is versioned and can be downloaded on a public repository from this URL: https://doi.org/10.57745/B35XCS.

3.6.3 | Reuse of works

Figure 16 shows the mean FWCI by area of knowledge. The median FWCI computed over all the articles is 1.1, meaning that overall articles including results collected from temporal methods are 10% more cited than other articles in Food Science. The less cited articles are those dedicated to statistics. This can be explained either by an absence of need of new statistical techniques with regards to research objectives, by articles too complex to follow for scientists in sensory and food science but not statisticians, or by a lack of support in the most used software for the proposed data analyses. In any case, this result suggests that additional efforts should be made to make new statistical analyses more accessible to the sensory science community.

3.7 | Limitations

This article is based only on published research works, which make the conclusions not necessarily representative of practices outside of the academic context.

Despite all the care and double-checking, compiling data requires some subjective decisions. Thus, the reported percentages were rounded to the nearest five and should be considered general indications.

4 | CONCLUSION

This review describes 30 years of research involving multiattribute temporal methods by mapping the scientific literature in an exhaustive way (363 articles from 1991 to 2022). It presents how methods were developed, refined, disseminated, and informs about past and current trends in their implementations. The review enabled to identify some research gaps related to temporal sensory evaluation methods. The need for research on validity and reliability of the methods has been highlighted, as well as the need for recommendations about their implementation (choice of the method, type and training of the panel, number of subjects, use of replicates), and the analysis of temporal data (which analysis for which purpose).

Most temporal methods record perception closer to the moment of perception and could also be useful tools to better understand physiological mechanisms. However, some results presented in this review suggest that knowledge was built on a fragile foundation due to a lack of guidelines in the way that studies involving temporal sensory evaluation methods have been implemented, their data analyzed, and their results reported. This could have resulted in a misuse of the methods or in an overinterpretation of the results due to too much expectation about the validity and reliability of temporal data.

The objective of this review was not to point out bad practices but rather to suggest avenues for improvement that could help to increase the quality of the research. The sensory science community is invited to try the checklist and the template proposed with this article and to suggest improvements. We hope that FAIRification of data will in a near future make it possible to have a broader and more neutral body of information and opening up the prospect of meta-analyses that would allow more substantiated recommendations.

AUTHOR CONTRIBUTIONS

Michel Visalli: Conceptualization; writing—original draft; data curation; formal analysis; visualization; methodology; validation. **Mara Virginia Galmarini**: Conceptualization; writing—original draft; methodology; validation; visualization; formal analysis; data curation.

CONFLICT OF INTEREST STATEMENT

The authors have declared having no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data extraction form can be downloaded here: https://doi.org/10.57745/IXP1PR.

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SUPPORTING INFORMATION

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How to cite this article: Visalli, M., & Galmarini, M. V. (2024). Multi-attribute temporal descriptive methods in sensory analysis applied in food science: A systematic scoping review. *Comprehensive Reviews in Food Science and Food Safety*, *23*, 1–45. https://doi.org/10.1111/1541-4337.13294