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Temporal Domination of Sensation: When Building Dishes, Let’s Take Temporality into Account

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The time course perception of dishes is important for their appreciation, and the culinary design of flavour by chefs could be improved if based on careful analysis of systems. Temporal Domination of Sensations (TDS) is an analytical technique that fills the gap between static multidimensional sensory profiling and dynamic unidimensional Time–Intensity (TI) by offering a way to assess simultaneously several attributes dynamically over time. The core idea of TDS is to no longer score intensities but to elicit dominances, which is simpler for untrained individuals. Recently, TDS was paired with liking, wanting and/or satiation evaluated quantitatively and dynamically during the intake of a full portion of a food, beverage or combination of the two. Further, Temporal Dominance of Emotions (TDE) has been recently proposed as a solution to more or less repeat a sensory profiling method (Clark & Lawless, 1994; Methven et al., 2010) several times. Conversely, another attribute may not be selected at all. During the tasting, the computer records a series of events (clicks), each composed of two items: time of the click (0 being the time at which the panellist starts to taste) and name of the attribute clicked. From these discrete data, a sequence of continuous dominances is defined by considering that an attribute attracts the attention of the taster. That is the concept of “dominance”. In its present form, TDS cannot realistically deal with more than approximately 12 attributes (Pineau et al., 2012). Profiling products with so few attributes sometimes requires gathering several sensory attributes into a single attribute (for instance, “fruity” to gather the several fruits one can perceive in that type of product). It is thus possible to define briefly (using words and/or references) each attribute to untrained consumers. Then came the idea of asking panellists only for these successive dominances without associating each of them with an intensity score, and TDS thus became feasible for a consumer panel (Albert et al., 2012; Brachet et al., 2014, Visalli et al., 2016). Indeed, it only requires a quick familiarization with the data acquisition device, thanks to the evaluation of one warm-up product.

In practice, the computerized TDS system shows the panellist the entire list of attributes on a computer screen (Figure 86.1). The panellist is then asked to click on the start button as soon as the product enters his/her mouth and then to consider which of the attributes is perceived as dominant. Thereafter, each time the panellist feels the perception has changed, he/she selects the new dominant attribute, until the perception ends. During the testing of one product, the panellist is free to select an attribute several times. Conversely, another attribute may not be selected at all. During the tasting, the computer records a series of events (clicks), each composed of two items: time of the click (0 being the time at which the panellist starts to taste) and name of the attribute clicked. From these discrete data, a sequence of continuous dominances is defined by considering that an attribute remains dominant until another one is clicked.

The procedure plots each attribute as a curve (Figure 86.2). For each point of time, the proportion of runs (subject × replication) for which the given attribute was assessed as dominant is calculated. These proportions are smoothed over time (e.g., using moving averages or splines) and displayed as curves of the evolution...
of the dominance rate for each attribute. The product depicted in Figure 86.2b can be described as dominated by crunchiness perception at the beginning of the sequence, followed by brittleness and finally stickiness. The time-standardized representation (Figure 86.2b) takes individual differences in onset and duration of evaluation into account. To illustrate this, one can think about a beer in which the first sensation quoted might be bitterness, but after several seconds, a rising perception of an aroma (say, malty aroma) occurs, whereas the bitterness remains the most intense. In that case, the panellist perceiving the malty aroma must click on the corresponding attribute in the list, because this aroma did trigger his attention.

During panel training, this concept can also be illustrated through sounds, the attributes being the different instruments of a band. For the panellists, it is generally easy to understand that the most triggering/dominant perception is not necessarily the loudest one but the one bringing the biggest change in the melody. TDS with intensity being also a tool for the trained panel, the question of monitoring panellist performances has been raised by a few authors (Meyners, 2011; Hutchings et al., 2014; Lepage et al., 2014), but none of these approaches has been universally accepted. However, TDS with no intensity as a technique for consumers is not concerned with this request for performance investigation. Furthermore, we have unpublished data suggesting that trained panellists may use fewer attributes than untrained consumers and may take more time to pick the first one, as if they were thinking too much during the task and/or possibly looking for some learned sequences in which the attributes are expected to be perceived. Similar results were recently suggested in a study (Rodrigues et al., 2016) in which the same panellists did TDS first without and then after some training. Such data, if confirmed, would even suggest that TDS is not well adapted to trained panels.

Today, TDS has been included in most software for sensory analysis. Readers interested in a review describing some of this literature can refer to Di Monaco et al. (2014). Although a large majority of these papers report studies based on trained panels, we speculate that TDS will be used more and more for consumer studies with no intensities. To some extent, TDS could be seen as a Check-All-That-Apply (CATA) method, making sense of the sequence and times at which people check the attributes. The popularity of CATA in consumer studies may soon propagate to TDS with no intensity. In fact, Temporal Check-All-That-Apply (TCATA) has been proposed recently as an alternative to TDS (Castura et al., 2016). TCATA only differs from TDS in that an attribute selected remains applicable until the panellist unclicks it. Therefore, several attributes could be applicable at a given time, which is perfectly acceptable from a sensory point of view. However, we personally do not believe that a consumer could look for new applicable attributes and, at the same time, wonder whether the attributes currently selected are still applicable. Indeed, in most cases, the perception of one intake of a product lasts for 30–60 s, which is too short for a complicated task of selecting and deselecting attributes. We found that the TDS task was at approximately the right level of difficulty for an untrained consumer, while the TCATA task is obviously more complicated.

Pairing TDS with Liking, Wanting and Satiation

The justification for using TDS with consumers is, of course, to relate temporal descriptive data to liking evaluation of the products given by the same consumers. Several studies (Bouteille

FIGURE 86.1 TDS evaluation screen of the texture of a cereal snack product.

FIGURE 86.2 TDS curves of a cereal snack product (a). TDS curves of the same product after left–right time standardization (b).
et al., 2013; Paulsen et al., 2013; Bemfeito et al., 2016) used a trained panel for TDS and a consumer panel for liking. Other studies (Oliveira et al., 2015; Ares et al., 2017) used panels of consumers who did TDS or TCATA and provided a static liking score afterward. However, the challenge was to use a dynamic liking evaluation in order to correlate sensory and hedonic kinetics. Indeed, there are sufficient data suggesting that liking is temporal (Lee, 1986; Taylor and Pangborn, 1990; Veldhuizen et al., 2006) and further, that its temporality allows product discrimination (Sudre et al., 2012; Delarue and Loescher, 2004).

An extension of TDS was proposed under the name Temporal Drivers of Liking (TDL) (Thomas et al., 2015) in two different variations. In the alternated-TDL (Thomas et al., 2016), the liking score is given between two successive intakes (e.g., sips or mouthfuls), whereas in simultaneous-TDL (S-TDL) (Thomas et al., 2017), the liking scale is available on the same computer screen as the TDS panel of attributes. The alternated-TDL of TDS is easier than the S-TDL, during which the panellist has to perform TDS and temporal liking concurrently during the perception of a mouthful of food or sip of a beverage. Additionally, more research and data are necessary for validating the ability of consumers to use TDL protocols.

The alternated-TDL of a full portion of the product involves a large number of intakes and thus a large number of liking scores in order to show a potential between-intake dynamic of liking. Evaluating the full portion of a product opens the door to monitoring the evolution of wanting and/or satiation. These measures can be as interesting as, if not more interesting than, monitoring the liking. Examples of such studies can be found in Thomas et al. (2016); Thomas et al. (2017); Thomas et al. (2018). These studies emphasize a double level of temporality: within versus between intakes. We found that the between-intake scale often induced more temporal variation in both perception and liking. However, more research is necessary to investigate whether asking for several variables between numerous intakes is not too difficult for consumers and does not result in cognitive correlations between these variables. The need for developments of multiple-intake protocols was clearly stated by Delarue and Blumenthal in their thorough review of temporal aspects of consumer preferences (Delarue and Blumenthal, 2015). In line with this recommendation, a recent study (Rocha-Parrá et al., 2016), based on three consecutive sips of a new beverage, combined a dynamic TI evaluation of liking with facial expression and concluded that liking increased over sips as a result of a decreasing intensity of negative emotions.

Temporal Dominance of Emotions (TDE)

TDS was used recently to evaluate modulations of the temporality of chocolate perception induced by emotional states mediated by different types of music listened to by consumers during chocolate consumption (Kantono et al., 2016). In this study, emotions were assessed only at the end of the tasting. However, it was suggested that emotions elicited when tasting a food product may also be temporal (Jager et al., 2014). These authors consequently proposed the Temporal Dominance of Emotions (TDE) as a straightforward extension of TDS by simply replacing sensory with emotional attributes. In their example, it was clear that flavoured chocolates elicited more arousal and stimulating attributes than plain chocolates, which elicited more ‘boring’ and calm attributes. However, this difference truly due to emotion or just an expression of differences among chocolates in their level of novelty? Whether emotions can be measured by a questionnaire is debatable, but those who adopt this idea should also consider TDE.

No Dominance and Dual-TDS

Assuming that a single attribute is dominant at any time and remains dominant until a new one is selected, TDS also assumes that it is not possible to have a period of no dominance or to have two attributes dominant at the same time. However, a panellist might no longer perceive the attribute as dominant without having a new dominant attribute in mind or might perceive two dominant attributes simultaneously. The latter often occurs when attributes belong to two different sensory modalities. In that case, a panellist is likely to choose the dominant attribute from the sensory modality that is easier to describe. For instance, it was observed for many products that texture attributes are more likely to be selected as dominant than flavour attributes, resulting in poor temporal flavour profiles. Hold-Down and Dual-TDS were proposed recently to overcome these problems.

In Hold-Down TDS, panellists are instructed to hold down the button of the mouse or, in the case of a tactile screen, to keep their finger on the button until dominance ends. When the panellist releases the mouse button, or removes their finger from the screen, a period of no-dominance starts automatically until the panellist presses another button or eventually, the original one. In classical TDS, another simple way of allowing for a no-dominance period is simply to make it possible to re-click on the highlighted button to switch it off, thus starting a no-dominance period. In both solutions, a period of no-dominance is initiated, and it ends when the panellist selects a new dominant attribute. In Dual-TDS, attributes belonging to two different modalities are arranged on the computer screen in two columns, and panellists are instructed that they can have one attribute dominant in each column at the same time. In practice, the selection of an attribute switches off only the dominant attribute from the same column and not the other one. Dual-TDS can also be combined with the two ways of accepting no-dominance periods. If Hold-Down TDS is used in Dual-TDS, then panellists have to use one finger from each of their two hands to click and re-click on attributes of both columns. Software for sensory data acquisition is expected to offer these new protocols in the near future, and at least one already does (TimeSens, 2019).

Using TDS-Liking for Descriptive and Hedonic Evaluation of Food Pairing

In an experiment where consumers sampled a piece of cheese between sips of wine, which was TDS-profiled and liking-scored,
Galmarini and co-workers provided strong data suggesting that cheese makes the wine taste different and better (Galmarini et al., 2016). In another experiment, in which intakes of cheese were evaluated and sips of wine were consumed between the intakes of cheese, wines moderately changed the taste of cheeses but definitely not their liking (Galmarini et al., 2017a). This raised interesting questions about the certainty of liking and furthermore, offered a new and useful technique for studying any kind of food combination. Further, the same authors also proposed a way to freely assess a pair of products in an S-TDL way (Galmarini et al., 2018). In this protocol, each panelist is free to take a sip of wine and a mouthful of cheese at any time and in any order, as he/she will do in natural conditions of wine and cheese tasting. Of course, TDS curves are no longer meaningful on this data; however, analysis of variance (ANOVA) and multivariate ANOVA (MANOVA) of durations of dominance by periods allowed analysis of this data and knowledge to be gained on perception of wine-cheese combinations.

### A Need for TDS Data Analysis Refinements

Typical analysis of TDS data relies mostly on the visual inspection of the TDS curves that represent, for each attribute, the evolution across time of the proportion of panellists selecting that attribute as dominant (Pineau et al., 2009). Randomization tests were proposed for making a statistical inference based on TDS data (Meynens and Pineau, 2010), but these tests require very long computations that have to be adapted to each situation, making them almost impossible to use routinely by a sensory scientist. We also do not support the idea of extracting TDS curve parameters for analyzing them by principal component analysis (PCA) or analyzing the curves by a multivariate analysis method such as PARAFAC (Rodrigues et al., 2015) because, in contrast to TI, those curves are not produced by individuals but are an approximate visual summary of the panel.

It is the opinion of the author that a more appropriate way of testing product differences from TDS data is to use ANOVA and MANOVA of dominance durations (time between a citation and the next one). A nice refinement consists of incorporating into those linear models a ‘period’ effect splitting the total time into a few (usually three: beginning, middle and end of perception) consecutive periods (Galmarini et al., 2017b). It is thus possible to test product differences by period and to assess whether product perception evolves differently among samples. Finally, sensory trajectories can be visualized from a PCA biplot based on a data table containing dominance durations of products by periods as observations and attributes as variables. If product trajectories are not parallel on that biplot, then differences in temporal perception of the products are evident (Pineau and Schlich, 2015).

It should be noted that all these methods implicitly assume panellist homogeneity in temporality perception. In cases of poor homogeneity (which is likely to occur with a consumer panel), curves should not reach significance very often, and ANOVA and MANOVA should not exhibit period and product by period interaction effects. To circumvent this limitation, Lecuelle et al. (2018) recently proposed analysing TDS data with an adaptation of semi-Markov chains. This technique estimates the probability of transition from one dominant attribute to another and allows those probabilities to be different among a number of periods automatically determined to maximize a likelihood function. This stochastic framework allows researchers to further segment the consumer panels into clusters of homogeneous consumers in terms of temporal perception (Cardot et al., 2019). We hope that this new framework will be a new deal for the analysis of TDS data.

### Last But Not Least: What Is Dominance?

The extensive literature on TDS validates its usefulness in many areas of applications. Panellists who have done TDS usually like it because they find it very easy to do. Overall, we can say that TDS is easily measuring something useful. However, do we really know what is measured? We defined dominance as what attracts your attention at a given time, but the reasons for raising your attention may be diverse among individuals and also across types of product. It can be due to the perception of a new attribute, the extinction of the perception of a former attribute, a sudden variation in the perceived intensities of one or several attributes, a cognitive search for novelty, or a willingness to sample as many attributes as possible. We have to admit that we lack basic knowledge on what dominance is, and we hope that psychologists and physiologists will address this topic sooner or later.

### REFERENCES


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