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What is dominance? An exploration of the concept in TDS tests with trained assessors and consumers

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Abstract

TDS describes the evolution of the dominant sensory attributes during consumption. Dominance can be assessed as the sensation that captures the attention, the most striking, or the new sensation that pops up, but not necessarily the most intense. This wide definition implies that individual assessors within a panel might assess dominance differently, and even the same assessor could be using different strategies for determining the dominant attribute the same product evaluation. In this context, the aim of the present work was to explore how trained assessors and consumers conceptualize dominance and how the different interpretations and definitions of dominance might influence results of a TDS test. Two studies were performed, one study with a highly trained panel of 10 assessors and another study with 108 consumers. Trained assessors evaluated three bread samples via TDS and their conceptualization of dominance was explored through an immediate retrospective verbalization task. Consumers evaluated the temporal perception of a commercial milk chocolate sample and answered a series of open-ended questions. Results showed that dominance is a complex construct that is not related to a single aspect of sensory perception, and that different conceptualizations of dominance within a panel can hinder an accurate interpretation of results from TDS studies. Various aspects of dominance are highlighted and discussed: how attributes are selected, which are the drivers of transitions between dominant attributes, how the competitive effects of attributes and modalities are manifested, how some phenomena like dumping or dithering could happen at some stages and why. Practitioners are advised to ensure that their interpretation of TDS data is made within the context of the dominance definition they instructed assessors to use. Implications of the results for the application of TDS with trained assessors and consumers are discussed.

Keywords: temporal methods; TDS; sensory characterization; dominance; retrospective verbalization
1. Introduction

Temporal Dominance of Sensations (TDS), which describes the evolution of the dominant sensory attributes during consumption, has become one of the most popular temporal methods in sensory and consumer science (Cadena et al., 2014; Di Monaco, Su, Masi, & Cavella, 2014). TDS is a multi-attribute method in which assessors are presented with a list of sensory attributes and are asked to select the attribute perceived as dominant at each moment of the evaluation (Pineau et al., 2003; 2009). This method is based on the concept of dominance, which makes it conceptually different from all other sensory methods, such as time-intensity (Meyners, 2010).

Dominance does not have a unique definition. Instead, several different definitions for this complex construct can be found in the literature (Pineau & Schlich, 2014). Labbe et al. (2009) and Albert, Salvador, Schlich, & Fiszman (2012) only considered intensity in their definition, conceptualizing the dominant attribute as "the most intense sensation". Other studies refer to the ability of an attribute to catch assessors' attention. Lenfant et al. (2009) defined the dominant sensation as the one that "triggers the most the attention at a point in time", whereas Bruzzone, Ares & Giménez (2013) defined it as "the sensation catching the attention of the assessors at a given time, not necessarily being the one with the highest intensity". References to marked changes in the sensory characteristics of products at a given time have also been included in the definition of dominance. Pineau et al. (2009) and Rodrigues et al. (2016) referred to the dominant attribute as "the new sensation popping up, not necessarily the most intense". The majority of the most recent studies have referred to the "ability of sensory attributes to catch assessors' attention" for defining dominance (Cadena et al., 2014; Di Monaco et al., 2014). In this sense, the ISO standard for establishing a sensory profile (ISO, 2016) recommends that the dominance sensation in TDS should be "defined to the assessors as the sensation that catches his/her attention at a given time, which does not mean that this sensation has to be very or the most intense in the product". Similarly, Pineau & Schlich (2014) have recommended that
dominance refers to the sensations that catch assessors’ attention at a given time, explaining to assessors that dominant sensations are perceived suddenly but are not necessarily the most intense sensations. However, it is still not clear how assessors understand dominance or what determines the attentional capture of sensory attributes during a TDS task (Di Monaco et al., 2014).

In summary, three main aspects of sensory perception have been cited in the definition of dominance: attentional capture, sensory changes during consumption, and attribute intensity. Although changes during consumption and attribute intensity are expected to modulate the attentional capture of sensory attributes, no study has explicitly investigated the relationship between these three concepts. Which of the three definitions of dominance is used has important implications for the interpretation of TDS data, as each definition refers to a different aspect of sensory perception. Therefore, it is necessary to study how assessors conceptualize dominance in order to accurately describe results from TDS.

Furthermore, different assessors within a panel may use different criteria for selecting the dominant sensation, and even the same assessor evaluating different products might change how they determine which attribute is dominant. These differences can lead to over-dispersion in the TDS data. Heterogeneity in the conceptualization of dominance can hinder the ability of TDS to provide a detailed description of how the sensory characteristics of products change over time, particularly for complex products and/or when multiple sensory modalities are simultaneously evaluated (Ares et al., 2015). In this sense, evidence of heterogeneity in how assessors select the dominant attribute can be found in several studies: in several instances maximum dominance rates were lower than 0.40, whereas in other cases, several attributes have been reported to simultaneously show low and non-significant dominance rates (Labbe et al., 2009; Lenfant et al., 2009; Meillon, Urbano, & Schlich, 2009; Teillet, Schlich, Urbano, Cordelle, & Guichard, 2010; Saint-Eve et al., 2011). This suggests that in many circumstances
assessors tend to select different sensations as dominant and that less than 40% of the assessors agree on which is the dominant sensation throughout the evaluation.

TDS has been used with both consumers and trained assessors for sensory characterization of a wide range of products (Di Monaco et al., 2014). The conceptualization of dominance may be influenced by training and therefore differences in how consumers and trained assessors select the terms that catch their attention at each moment of the evaluation. According to Meyners (2010), assessors trained in classical descriptive methods might base their conceptualization of dominance on attribute intensity. In this sense, Meillon et al. (2009) suggested not to over-train the sensory panel in order not to encourage assessors to select attributes in the same order for all samples. In addition, Rodrigues et al. (2016) recently reported differences in the temporal sensory profiles obtained using TDS with consumers and trained assessors.

In this context, the aim of the present work was to explore how trained assessors and consumers conceptualize dominance. This information is expected to contribute to a more accurate interpretation of results from TDS.

2. Materials and Methods

The empirical work comprised two studies, one conducted with trained assessors and the other conducted with consumers. In both studies, assessors were asked to complete a TDS task with samples belonging to different product categories. After the task, qualitative explorations were undertaken to better understand the motives that underlie the selection of the attribute that caught each assessor’s attention at each moment of the evaluations. Details on these studies follow in the next two sections.

2.1. Study 1: Dominance exploration with trained assessors
2.1.1. Trained assessors

Study 1 was run at Nofima (The Food Research Institute) in Ås, Norway. The tests were performed in a sensory laboratory designed according to guidelines in ISO 8589 (2007) with separate booths and electronic data collection using EyeQuestion Software (Logic8 BV, Netherlands). The panel at Nofima consists of 10 external assessors, hired solely as trained assessors, some of them with more than 20 years of experience. They were selected and trained according to recommendations in ISO 8586-1:2012 (ISO, 2012) and are regularly trained, tested and controlled for their performance. The sensory panel has six years of experience of using the TDS method with a range of different food products including liquids, solids, and semi-solids. Following recent recommendations, training of the panel for TDS was focused on the identification of the attributes to improve selection of the dominant sensations rather than on the concept of dominance itself (ISO, 2016). In addition, training sessions to familiarize the assessors with the data collection procedure were conducted.

2.1.2 Sample selection and preparation

In a pre-test, QDA and Temporal Dominance of Sensations (TDS) were performed on eight Norwegian commercial bread products. Based on these results, three white and whole-grain bread samples, representing a good spread of static and dynamic sensory profiles, were selected for subsequent evaluation, using the same-trained panel. All bread products were purchased early in the morning, sliced in the shop/store, put into plastic bags, and stored at room temperature. Immediately before each session, bread slices were cut into 35-mm diameter circles, then placed immediately into a plastic container with a lid identified by a 3-digit blinding code. The size of the bread circles was determined based on pre-test feedback, with the objective of allowing assessors to put the entire piece in their mouths for evaluation.
2.1.3. Temporal dominance of sensations

Attributes were selected by the panel for the temporal evaluation in an open discussion with the panel leader in a preliminary session, and were chosen to enable the characterization of samples, which from the pre-test were known to have particular perceptual differences. The following 9 attributes comprised the TDS attribute list: acid, sweet, salty, bitter, juicy, coarse, chew resistance, doughy, soft. Samples were fully randomized over assessor, product, and replicate. Assessors were instructed to put the entire bread sample (35-mm diameter circles) into the mouth and evaluate the most dominant attribute at all times, as the sensation that caught attention at a given time, not necessarily the most intense. They were presented with the 9 flavour and texture attributes (listed above) on the computer screen. They simultaneously put the bread sample in their mouths and clicked the “Start” button. At each moment they were free to choose any attribute as dominant without restrictions; i.e., any particular attribute could be dominant for as long or as often as deemed necessary by the assessor. The evaluation ended at the time the assessor was ready to swallow, which the assessor indicated by clicking the “Stop” button. Attributes were randomized between assessors and replicates but the same assessor received always the same order for all products within each replicate. Attributes were displayed in a radial pattern on the screen (Figure 1). Samples were evaluated in triplicate in the TDS test used for selecting samples for the dominance exploration task.

2.1.4. Dominance exploration: retrospective verbalization

The qualitative exploration of the assessor conceptualization of dominance was performed through an immediate retrospective verbalization task (Ericsson & Simon, 1993), which was recorded as audio on a tablet device, by each assessor, immediately after the tasting (voice recording). Protocol analysis techniques, like think aloud, concurrent verbalization and retrospective verbalization, have been used by psychologists for decades to understand the thought process behind a task, and more recently these techniques have been used in
marketing and consumer science (Sudman et al., 1996; Darker & French, 2009; Jaeger et al. 2013). Recorded verbalization data is similar to measurements like eye fixations, or sequences of moves, in the way that they are related to the internal cognitive processes and to the information attended to (Ericsson & Simon, 1993; Guan et al., 2006). How well this information is retrieved depends on the interval between the acquisition and the recall, so it is important for the verbal data to be captured as soon as the processes finalise, so there will still be information stored in the short-term memory. Retrospective verbalization tasks have been shown to provide a reliable account of what people attend to, their inferences and strategies in completing complex tasks, with a low risk of introducing fabrications (Guan et al., 2006). To aid the recall of the specific cognitive processes, subjects can be asked to regenerate it by redoing the task, and use this information to explain the general procedure they may have used. The verbal probe, or question asked to the subject, can be directed to a specific moment of the process (Ericsson & Simon, 1993). In this case, two sessions of qualitative exploration through retrospective verbalization were run with the panel, with different objectives. The two sessions were held two weeks apart:

- Session 1 focused on the selection of and transitions between dominant attributes
- Session 2 focused on the exploration of competitive perceptions at each time slice

Both sessions were run with the same procedure. Assessors evaluated the sample as they would normally do in a TDS task, and immediately received again the same sample to regenerate their cognitive process by redoing the task and explaining their assessment (retrospective verbalization). For each of the three bread samples, the retrospective verbalization procedure consisted of three steps:

1) Assessors evaluated the sample via TDS as described above, through only one evaluation (no replicates). The panel leader immediately printed the time sequence of their individual evaluation and handed it to each of the assessors (see example in Figure 2).
2) Assessors re-tasted the same sample (redoing the task) looking at their individual plot and focusing on the probe question. The probe question in session 1 was “Please explain how you selected the dominant attribute and why you changed to a new attribute”. The probe question in session 2 was “Please describe the competitive perceptions at each time slot (the attributes that are perceived at the same time but you haven’t selected as dominant)”.  

3) Assessors immediately explained the general procedure they used (retrospective verbalization of the cognitive process) by recording it as audio in a tablet device (voice recording). They repeated this procedure for the three bread samples in a monadic sequence, following a random balanced rotation. Panellists did the retrospective verbalization individually and alone in a sensory booth.

Insert Figure 2 about here

2.2. Study 2: Dominance exploration with consumers

2.2.1. Participants

A total of 108 consumers from Montevideo (Uruguay) participated in Study 2. They were recruited from the consumer database of the research group who authored the study based on their milk chocolate consumption, as well as their interest and availability to participate. Participants (65% female) were 18 to 63 years old. Participants gave written informed consent and received a small gift for their participation.

2.3. Experimental procedure

Consumers were asked to evaluate a commercial milk chocolate sample. They were asked to review the attributes prior to the evaluation to facilitate the task of locating attributes
during the TDS evaluation. They were instructed that they had to select, from a list of terms, the sensation that caught attention at a given time, not necessarily being the most intense. Consumers had to click a “Start” button concurrently with taking a bite of sample, and to immediately commence sample evaluation. The duration of the task was 60 s.

The list included 10 terms involving both flavour and texture attributes: bitter, brittle, chocolate flavour, hard, melting, off-flavour, soft, sticks to teeth, sweet, vanilla. Terms were selected based on results of previous consumer studies (Ares et al., 2017) and pilot work with a small group of consumers to check understanding of the terms. To avoid list order bias, the order of the attributes was balanced between assessors following Williams' Latin square design. No definition of the attributes was given to consumers.

After the evaluation of all samples was completed, consumers were asked to type their responses to the following open-ended questions to explore their conceptualization of dominance:

i) Why did the attributes you selected catch your attention during the test?

ii) Did you perceive any other sensations simultaneously with the sensation that caught your attention? If yes, why did you not select them?

iii) What made you change your selection of attributes during the task?

Testing took place in standard sensory booths that were designed in accordance with ISO 8589 (ISO, 2007), under artificial daylight and temperature control (22 °C). Data collection was carried out using Compusense Cloud 7.8 (Compusense Inc., Guelph, Canada).

2.3. Data analysis

2.3.1 TDS curves

The TDS curves for the study conducted with the trained assessor panel were obtained by plotting the dominance rate of each of the sensations at different points of the eating period,
for each sample, across the panel (Pineau et al., 2009). The data from each subject were
standardized according to individual mastication durations (Lenfant et al., 2009), with the first
and last timepoints corresponding to when the assessor clicked “Start” and “Stop”, respectively.

2.3.2. Dominance exploration with the trained panel

The trained panel described their sensations in Norwegian. Recordings were transcribed
and translated; two researchers checked the translations. Translated transcriptions of the
immediate retrospective verbalization task were then qualitatively analysed, independently, by
two researchers with previous experience in content analysis. Afterwards, the researchers met
to agree on the interpretation of the data and overall conclusions of the study. They followed
good practices of coding protocols, identifying and organizing utterance segments by type, and
relevant sentences and ideas were organized in topics for discussion. The objective of this part
of the study, however, was not to calculate percentages of citation of the different categories
because of the low number of subjects in a trained panel (n=10), but rather to qualitatively
discuss the main procedures used by the assessors when evaluating dominance in the TDS
task.

2.3.3. Dominance exploration with consumers

Consumer responses were analyzed using inductive coding (Krippendorf, 2004). This
process includes open coding, creating categories and abstraction. Responses were merged
into mutually exclusive by two researchers with previous experience in content analysis. After
the individual classification of each researcher, a meeting was held to select the final categories
by consensus. The percentage of consumers giving responses within each category was
determined.

3. Results
In the following sections, results are presented by type of assessor who completed the task. It is beyond the scope of the paper to present or discuss the TDS curves for all the products that were evaluated. These curves are only included to interpret the qualitative information provided by the trained assessors. Interested readers may contact the authors for further details.

3.1. Dominance exploration with the trained panel: Retrospective verbalization task

Figure 3 displays the dynamic profiles of the three selected samples to perform the qualitative exploration of the concept of dominance with the trained panel. The objective of having samples that were very different in sensory profiles was accomplished; the diversity in flavour and texture was aimed in order to generate the richest possible information in the qualitative step. The samples selected were a white bread (a), a half-coarse bread with seeds (b) and an extra coarse bread (c).

Selected phrases of the feedback by individual assessors are used in this section to exemplify the main outcomes of the qualitative exploration and to discuss various aspects of the implications of dominance evaluation within a TDS test.

3.1.1 Heterogeneity of the conceptualization

Heterogeneity in the conceptualization of dominance was found. Most aspects of the definition of dominance utilised in previous works were highlighted by the panel: attentional capture, sensory changes, and attribute intensity were all mentioned, for all samples.

In line with the definition of dominance as the sensation that “triggers the most the attention” (Lenfant et al., 2009; Bruzzone, Ares & Giménez, 2013), many comments by the
panel referred to the attentional capture of sensory attributes. Some sensations were more attended to, while others remained in the background: “The first thing that strikes me the most is its softness, but it’s also very juicy and sweet”; “In the background I can also notice saltiness and sweet and wheat flour taste, but the texture is what’s dominating”; “Coarse. The acidity lurks in the background the whole time, as well as the chewing resistance”.

The perception of the dominant attribute as “the new sensation popping up” (Pineau et al., 2009; Rodrigues et al., 2016) was widely mentioned: “Suddenly there’s a feeling that it becomes very juicy”; “It then becomes juicy, but keeps its acidity” (this assessor chose the attribute Juicy as dominant); “Eventually it becomes sweet and sourdough-ish while keeping its tenacity” (this assessor chose Sweet); “there’s a saltiness that pops up”.

Trained assessors also referred to the dominant attribute as “the most intense sensation” (as in Labbe et al., 2009; Albert et al., 2012): “Very soft. Doesn’t actually taste a lot”; “it becomes very juicy”; “Relatively good chewing resistance with a very sweet taste” (Sweet was selected as dominant by this assessor); “it had a lot of chewing resistance, but the coarseness was stronger”.

3.1.2 Drivers of the transitions between attributes

In general, qualitative data showed that most transitions between dominant attributes were driven by “big”, noticeable perceptual changes due to new sensations popping-up, sensations fading away, and events like biting through seeds, as exemplified by the following comments: “Immediately, there’s a lot of taste at once. Acidic with a lot of taste of grains”; “Suddenly there’s a feeling that it becomes very juicy”; “Saltiness that pops-up and catches your attention before ending up as pretty bitter”; “Nutty when you bite through the whole grains”; “After you’ve chewed so much that the feeling of softness and acidic taste disappears, a salty taste appears”; “Then it just disappears and there’re no feelings of texture left and the saltiness becomes apparent”; “When this stops there’s an acidic and salty taste that appears”.
3.1.3 The role of oral processing in the evaluation of dominance

From the analysis of the qualitative data, it became apparent that texture and flavour might be competing in a TDS test as modalities rather than as specific, single attributes. Examples described by the trained panel for the three samples are given below, with underlined text (emphasis ours) highlighting the most important ideas:

“It’s soft immediately when entering the mouth, but you chew past that fast and it becomes sticky around the teeth, also with a doughy feeling. Then it just disappears and there are no feelings of texture left and the saltiness becomes apparent. … That lasts until you’re left with only juiciness. It dissolves very fast”.

“Starts out with a lot of chewing resistance, but early on you start chewing at the grains so the word ‘coarse’ springs to mind immediately as soon as you chew some of those hard bits. As long as they’re there, that (coarseness) is what’s dominating. Then it’s the salty taste that dominates when you’ve chewed past most of the coarseness. Then it’s basically the texture taking over again, there’re no taste attributes apparent enough, except the saltiness, so it’s just how it feels in the mouth left – that it’s doughy and then juicy at the end”.

“A very noticeable chewing resistance when you put it in your mouth, then there’s not a lot happening before it goes from having chewing resistance to becoming sticky and doughy in the mouth. The chewing resistance and the doughiness is what’s dominating above all taste related attributes before eventually the bitterness come at the end”.

This competition of sensory modalities can be described as “first texture, then flavour”, and can be seen clearly in the TDS curves for all samples (Figure 3). This effect could be a result of the type of sample or product category, as bread is naturally complex in texture and not particularly intense in terms of flavour as a category. However, both samples b and c could be considered “flavoursome” breads. This effect might on the other hand be arising from the natural
in mouth processing of a solid food, which has first to be broken down to being able to be swallowed.

3.1.4 Dithering and dumping effects

Both dithering (characterized by uncertainty and indecisive behaviour) and dumping effects (inflation of an attribute due to response restriction) (Lawless & Heymann, 2010) were evident from the qualitative results for all samples throughout the test. The limitation to only one dominant attribute could produce dithering, and the limitation of attribute availability might produce dumping. In addition, in follow-up discussions with the trained assessors, they stated experiencing frustration when there is only one attribute that can be chosen and when the one they look for is not available, because of the impossibility to describe the actual perception. Some examples below extracted from the qualitative exploration show the cognitive processes they follow when they experience attribute restriction:

“I've set it to salt, but at the same time it's also really soft. Went over to become doughy, but when I started to look for flavour attributes they were not available, like a taste of drawer, cloying and insipid. I just therefore put it as doughy the rest of the time.” In this case, the assessor did not find the flavour attributes she was looking for because the relevant attributes were not available in the list. Thus, because of this dumping phenomenon and hesitation (dithering) she opted to leave doughy selected as dominant until the end. Consequently, doughy was indicated to be dominant for longer than it was actually the dominant attribute.

“A bread with a lot of stuff going on at once. A bit hard to decide which attribute to put as dominant. A lot of taste and texture. I think it’s mostly a taste of sourdough, but I can’t get that across anywhere, but since it’s also pretty coarse, I’ve set that as dominant most of the time.” In this case, the assessor was overwhelmed by the complexity of the perception and could not decide (dithered) before selecting the dominant attribute. This phenomenon was triggered by the absence of some of the attributes she was looking for from the attribute list. Therefore, the
assessor chose an attribute she did perceive, although it was not necessarily the dominant one, and did so for a long period of time.

“Immediately very juicy and spongy, but there’s also a lot of taste at once, but it’s hard to place in the circle. Can’t really find where to put it. I think it’s rye grains, but maybe a bit salty, but the only taste I’ve set it to is bitter.” In this case, the assessor dithered before selecting the dominant attribute; although some attributes that were perceived (salty, bitter) were available, and she decided to select bitter for the whole duration (dumping).

“My experience with this method is that if you perceive a taste very strongly that’s not in the list, you can only choose a taste (that is there) and it’ll seem present for longer than it realistically is if there were more attributes to choose from.” This last example summarizes part of the phenomenon in one of the assessor’s own words.

3.2. Dominance exploration with consumers

Figure 4 shows the TDS curve of the chocolate sample evaluated by consumers. As shown, four attributes were significantly dominant throughout the evaluation: hard, brittle, chocolate, flavour, sweet and sticks to teeth. Except for hard, the maximum dominance rates of the attributes were close to 20%, which suggests heterogeneity in how consumers identified the attribute that caught their attention was found.

Responses to the open-ended question provided additional evidence of the diversity of factors underlying consumer conceptualization of dominance. As shown in Table 1, when consumers were asked about the motives underlying selection of the dominant attribute, they referred to different aspects of sensory perception, most of which have been included in the definition of dominance. Attribute intensity was the most frequent response: 34% of the consumers indicated that the sensation that caught their attention was the most intense. Consumers also referred to the sensation that caught their attention as the most striking sensation or the sensation that best described what they felt while consuming the product.
Changes in sensory perception and attributes that “popped up” were also mentioned as relevant motives for selecting an attribute as dominant, as exemplified in the following comment: “I selected the terms as the sensations I perceived while consuming the chocolate changed”.

Furthermore, some consumers explained why sensations caught their attention based on their expectations and hedonic reaction towards the product (Table 1). Some of the consumers stated that sensations caught their attention because the sensations did not fit their expectations based on their previous experiences with the product category, as shown in the following statements: “It caught my attention because of the comparison with other chocolates I’ve tried before” and “Because I felt different sensations compared to what I usually perceive when eating chocolate”. Other consumers indicated that they had selected the attributes they liked or disliked about the product: “Because I did not like its hardness” and “Because I liked how it melted in my mouth”.

When consumers were asked if they perceived other sensations simultaneously with the one that caught their attention, 72% gave an affirmative answer. The main reason for not selecting the sensations that were simultaneously perceived was that the non-dominant attribute had a lower intensity compared to the sensation that caught their attention (Table 1). However, some of the consumers (21%) indicated that they did not select these secondary attributes because the test only allowed them to select one characteristic at a time and therefore they had to choose only one of those characteristics as the attribute that caught their attention: “I did not select them because I could only select one term at each time”. Other consumers just indicated that they did not select other sensations because they did not catch their attention, because they did not suddenly appear, or because they did not describe why they liked or disliked the product (Table 1).

Finally, consumers were asked to explain why they changed their selection of dominant attributes during the TDS task. As shown in Table 1, the most frequent response was related to
changes in the characteristics of the product during mastication, as well as changes in attribute intensity during consumption.

4. Discussion

The concept of dominance of sensory attributes is a key differentiating feature of the TDS method. Understanding the meaning of this complex concept is necessary for an accurate interpretation of results from TDS. However, several different definitions can be found in the literature (for a review, see Di Monaco et al., 2014). The definition of dominance has important implications for how results are interpreted, and researchers must ensure that their analysis and interpretation are made within the context of the dominance definition used.

Most recent studies have conceptualized the dominant attribute as the sensory characteristic that catches assessors’ attention at a given time (e.g. Ares et al., 2016; Pineau & Schlich, 2014; Thomas, Visalli, Cordelle, & Schlich, 2015), in agreement with the ISO standard (ISO, 2016). However, it is still not clear how assessors select the attributes that catch their attention at a given time. In the present study, two qualitative studies were conducted to understand how dominance is interpreted in practise and what determines the attentional capture of sensory attributes for trained assessors and consumers.

Heterogeneity in how assessors selected the dominant attribute was found in both the trained panel study and the consumer panel study in the present paper, suggesting that when dominance is associated with attentional capture, this concept is not one thing but many different things. When assessors were asked to explain why they selected the attribute that caught their attention, most aspects of the definitions of dominance used in previous studies were highlighted by both the trained assessors and consumers (Di Monaco et al., 2014).
Trained assessors mainly referred to the dominant attribute as the one that caught their attention, highlighting that both attribute intensity and sudden changes in the sensory profile were relevant aspects of dominance, as highlighted in the definition of dominance used by several authors (Albert et al., 2012; Labbe et al., 2009; Pineau et al., 2009; Rodrigues et al., 2016). In the specific case of consumers, results suggested that intensity was the main aspect of sensory perception involved in the assessment of dominance, followed by changes during consumption and comparison with expectations and previous consumption experiences.

Attribute transitions were mostly driven by “big” changes in perception, both for trained assessors and for consumers. Assessors seem to change from one dominant attribute to another when the perception of the selected attribute fades and/or when a new sensory characteristic pops up. In the specific case of trained assessors, selection of the dominant attribute during the evaluation of bread samples seemed to be determined by oral processing: assessors tended to choose texture attributes first, followed by taste attributes. Miller & Teates (1986) postulated that in animals, somatosensory information from oral movements and sensory perception information provided feedback linked to metabolic events, and used to recall how much of a food must be eaten to achieve satiety, as linked to the chewing process. The link of palatability and appetite provides an adaptive, evolutionary advantage (Hyde and Witherly, 1993), so it is not surprising that oral processing and temporal sensory perception would be related intimately. Recent studies on oral processing of solid foods (Witt & Stokkes, 2015) discuss the underlying physics of getting a food into a bolus, including how the temporal aspects of the dominant physical processes relate to the dominant textural properties. They propose a model determined by the food–saliva system, describing the two processes of decreasing food particle size and increasing salivary content until getting a swallowable bolus. From a food physics perspective, there will be three dominating stages: fracture mechanics, particle-saliva-oral interface mechanics, and bolus rheology. These stages will be intertwined with textural perception of hardness/crunchiness in the first stage, dryness/roughness in the second stage,
and stickiness/cohesiveness in the third stage. In the present study, there is no fracture involved in this bread category, but the evolution of the other textural attributes goes very much in line with that model. Witt & Stokkes did not include flavour in their model for development of a swallowable bolus, but it makes sense that during the oral processing stage driven by the particle-saliva-oral interface will be when the flavour perception becomes more important. Along the same lines, Devezeaux de Lavergne et al (2015) found for semi-solid gels a similar succession of appearance of dominant sensations in time for all samples, correlated to various fracture properties of gels. They linked the succession of appearance of dominant sensations to the influence of the QDA attribute order assessment and did not suggest oral processing implications, but the succession of appearance of dominant sensations described in this study could have resulted from the oral processing stages. Indeed, it could be interesting for future studies to look at the effects of oral processing steps in TDS evaluation across different product categories.

Hedonics and previous experience with the product category seemed to be relevant in consumers' conceptualization of dominance. According to consumer responses to the open-ended question, many times the dominant attribute was a sensation that did not fit their expectations, was surprising, or was liked or disliked. This suggests that selection of the dominant attribute for consumers may also be related to their hedonic reaction to the products, which can lead to heterogeneity in their responses. In this sense, Ares et al. (2017) has recently reported that maximum dominance rates tend to be lower for those samples in which heterogeneity in consumer hedonic responses are found.

Heterogeneity in assessor conceptualization of dominance may lead to high dispersion of TDS data, low dominance rates, and consequently few significantly dominant attributes and lack of ability to identify significant differences among samples. Evidence of heterogeneity in assessor conceptualization of dominance has been observed in several studies in which TDS curves show several attributes with similar dominance rates, several of which do not reach
dominance (Labbe et al., 2009; Lenfant et al., 2009; Meillon et al., 2009; Teillet et al. 2010; Saint-Eve et al., 2011). This reinforces the argument of Ares et al. (2016) regarding the fact that, at the aggregate level, TDS may miss relevant information about the dynamics of relevant sensory characteristics during consumption. In addition, using a broad and complex definition of dominance can make it difficult to interpret results from TDS tasks as it would be difficult to determine if a sensory attribute is dominant due to its high intensity, due to changes in the product during consumption, or perhaps because it is different from the product that assessors consume regularly.

Results from the present work showed that dumping and dithering biases are widespread in TDS tests conducted with both trained assessors and consumers. These biases are common in sensory profiling (Lawless & Heymann, 2010). In static descriptive analysis, they can be avoided with a good selection of attributes (no restriction of relevant ones) and a good training. Dumping has been described before in time-intensity tests by Bonnans & Noble (1993) and in multiple-time intensity tests (Clark & Lawless, 1994) due to the restriction in the number of attributes available during each evaluation. Dithering and dumping seem to be interrelated in TDS tasks due to the limitation of attributes in the list, the need to select only one dominant attribute at a time (which does not happen in multiple time intensity or descriptive analysis), and the time pressure to which assessors are subjected. Thus, it seems that these effects would play a more important role in TDS as compared to other descriptive methods. Therefore, although the noise caused by these two biases is expected to decrease with an increase in the number of evaluations, it should be taken into account that they still can lead to a relevant loss of information regarding the dynamics of the sensory characteristics of samples, particularly during the evaluation of complex products in which several sensory attributes are simultaneously perceived. Therefore, if practitioners aim at obtaining a detailed description of how the sensory properties of products change during consumption, TDS might not be the best methodological choice, as highlighted previously by Ares et al. (2015).
In addition, it is important to highlight that dithering and dumping might increase if assessors are asked to evaluate taste and texture in the same TDS task because fewer terms are available per modality. This raises concerns about simultaneous evaluation of different modalities in TDS tasks, as previously argued by Di Monaco et al. (2014). Therefore, if information about the dynamics of different sensory modalities during consumption is of interest, practitioners could consider conducting separate TDS evaluations for each modality, as proposed by Agudelo, Varela, & Fiszman (2015) with trained assessors. This methodological decision may have different implications when working with trained panels or consumers. Trained panels use technical words, longer lists of attributes, and are better at isolating and focusing on a particular sensory modality. Trying to cover two modalities while keeping a short list may restrict word choice on both modalities. If the objective is to understand how flavours and texture interact and how flavours are released during oral processing, a decision should be made whether to collect data in a single TDS task, or do it in two separate tasks and try to tie together their data *a posteriori*. However, if understanding consumer perception is the objective, it could be very reasonable to ask consumers about their total experience covering flavour and texture. In this case, the terms on the attribute list could be less technical and most often included fewer but more general words. Consumers will also evaluate products in a more natural way and therefore noticeability of or competition between particular textures and flavours might be of interest. If the experimenter chooses to run the experiment twice (flavour and texture separate) it has to be pointed out that trying to combine TDS timelines from different evaluations is not a straightforward procedure. In addition, it doubles the number of samples, introducing fatigue to the tasters.

In closing this section, it is important to highlight that sensory analysis conducted with trained assessors generally aims at obtaining objective sensory information, with as little subjectivity as possible. However, TDS tasks with trained assessors involve a much stronger aspect of subjectivity due to the wideness of the concept of dominance, unless this concept is
clearly defined as one unique concept they could agree on and measure accordingly. In this sense, it is important to stress that TDS has been claimed to require almost no training and that extensive training has not been recommended in TDS (Meillon et al., 2009; Pineau et al., 2009). According to Schlich (2017), trained assessors may look for learned sequences of attributes while evaluating the products. For this reason, training in TDS is mainly focused on the identification of sensory attributes and the method itself (ISO, 2016). Results from the present work suggest that the conceptualization of dominance as the attribute that catches assessors' attention may give rise to large individual differences, as it is not feasible to train people in what catches their attention. Therefore, in order to obtain an objective description of the dynamics of the sensory characteristics of products, practitioners are advised to focus on a specific aspect of dominance.

From this perspective, TDS may be more appropriate for consumers than for trained assessors. The use of consumers for TDS tasks might be more natural than considering a small group of trained assessors that in spite of receiving a particular definition of dominance do not use the same criteria to evaluate dominance in practice. When working with consumers one can obtain a more representative idea about what consumers emphasize as dominant and how this affect their product perception. However, it should be taken into account that consumer preferences may influence the conceptualization of dominance and increase the level of noise in the data. For this reason, dominance rates are expected to be low when large heterogeneity in consumer preference patterns exists, as recently reported by Ares et al. (2017). Thus, practitioners are advised to not exclusively focus on aggregate TDS data but consider other data analysis approaches based on individual data (Meyners, 2016).

5. Conclusions
Dominance is a complex construct that is not related to a single aspect of sensory perception. Results from the present work show that defining the dominant attribute as the characteristic that catches attention gives rise to a wide range of interpretations, which can result in heterogeneity in the responses and, consequently, information loss in TDS curves. The definition of dominance is then critical and knowing the underlying dimensions of the concept of dominance is key for data interpretation.

Although assessors can be trained to identify sensory attributes and familiarised with TDS, training them on the how to select the attribute that catches their attention seems not feasible. In the authors’ opinion, when working with trained assessors, contrary to recent recommendations, it may be better not to define the dominant attribute as the attribute that “triggers the most the attention (catching the attention) at a point in time”. Instead, it may be more appropriate to clarify which aspect of sensory perception assessors should attend to for selecting the dominant attribute: attribute intensity (e.g., “Select the most intense attribute at all times”) or changes in the sensory profile of products (e.g., “Select any sensation that you perceive to be undergoing big changes”). This type of definition may reduce individual differences and provide a more accurate and objective description of the dynamics of the sensory characteristics of products throughout consumption.

Results from the present work also raise concerns about the inclusion of terms related to different modalities in TDS studies with trained assessors. Simultaneous evaluation of different sensory modalities may cause dithering and dumping effects, leading to a relevant loss of information about the dynamics of the sensory characteristics of products during consumption. Further research should be conducted in order to make recommendations to practitioners regarding how the inclusion of attributes related to sensory modalities influence results from TDS tests.

When working with consumers, if the objective of the study is to describe the dynamics of the sensory characteristics of products during consumption, the influence of preference
patterns on the attentional capture of attributes should be taken into account, as some consumers tend to select the attributes they liked/disliked or those sensory characteristics that do not fit with their expectations. In the authors’ opinion, TDS with consumers may be more appropriate to highlight the sensory characteristics that are relevant for consumers when consuming a product. TDS seems to be a useful tool to understand how consumers perceive products, even with the noise of the divergent conceptualizations of dominance. In this sense, practitioners should be aware that sensory and hedonic expectations, as well as preference patterns, influence dominance. For this reason, low dominance rates are expected when heterogeneity in consumer preference exists and therefore, average TDS curves from consumers may not accurately describe how the sensory characteristics of products evolve during product consumption. Further research is still necessary to confirm that the dominant attributes are in fact good predictors of consumer hedonic reaction to products.

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References


**Figure captions**

**Figure 1.** Example of the radial attribute display for TDS with the trained panel, in the data collection software (Eye Question). Attributes are in Norwegian as used by the panel. In the example, the assessor has started the evaluation and has selected “saftig” (juicy) as dominant sensation.

**Figure 2.** Example of the time sequence an individual TDS evaluation that was handed to each assessor prior to the immediate retrospective verbalization task.

**Figure 3.** TDS dynamic profiles for three bread samples, which were used to perform the qualitative exploration of the concept of dominance with the trained panel: a white bread (a), a half-coarse bread with seeds (b), and an extra coarse bread (c). Only the names of the attributes that were significantly dominant are shown.

**Figure 4.** TDS dynamic profile for the chocolate sample evaluated by consumers. Only the names of the attributes that were significantly dominant are shown.
Table 1. Mention of the categories identified for each of the open-ended questions after the TDS task in the consumer study.

<table>
<thead>
<tr>
<th>Question</th>
<th>Categories</th>
<th>Consumers (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>i) Why did the attributes you selected catch your attention during the test?</td>
<td>The most intense sensation</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>The most striking sensation</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Sensations that “popped up”</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Sensations that did not fit previous expectations</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Liked/disliked sensations</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Common sensations in the product</td>
<td>1</td>
</tr>
<tr>
<td>ii) Did you perceive any other sensations simultaneously with the sensation that caught your attention? Why did you not select them?</td>
<td>No</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Yes...</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>but they were less intense</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>but the test only allowed me to select one, so I had to choose</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>but they did not catch attention</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>but they lasted less than the one I selected</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>but they did not suddenly appear</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>but they were not relevant for describing</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>liked/disliked aspects of the product</td>
<td>2</td>
</tr>
<tr>
<td>iii) What made you change your selection of attributes during the task?</td>
<td>Changes in the product during mastication</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>Changes in attribute intensity</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Sudden changes</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>The appearance of sensations I disliked</td>
<td>1</td>
</tr>
</tbody>
</table>
Trykk på **START** i det du tar hele prøve **292** i munnen. Velg så hvilken egenskap som **dominerer** til enhver tid. Når produktet er klar til å svelges, trykk **STOPP** og spytt ut prøven.

- Tyggenotstand
- Säftig
- Bitter
- Salt
- Syrlig
- Grov
- Myk
- Søt
- Deigete

**Neste**
Figure 3

(a) Dominance rate over standardized time for softness.

(b) Dominance rate over standardized time for various taste attributes.
Significance: 21
Figure 4

Dominance rate

Time (s)

Hard
Brittle
Chocolate flavour
Sweet
Off-flavour
Sticks to teeth
Significance: 15