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Understanding *dominance*: The effect of changing the definition of *dominance* when using TDS with consumers

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Abstract

Temporal dominance of sensations (TDS) is a widely used method to assess dynamic sensory perception. While TDS has been studied more extensively with trained panels, there is growing interest in testing the method with consumers. However, little is known about how consumers interpret the notion of "dominance" to decide which attribute they should select at a given point in time. This study investigated the effect of a changing definition of dominance on TDS results. Consumers, all of who had never undertaken a TDS test before, were recruited in three separate groups where they were briefly trained on TDS where dominance was defined as either: (a) most attention-catching sensation (TDS session), (b) most intense sensation (TIS session), or (c) most changing sensation (TCS session). Results showed that TDS curves were similar between all three sessions, suggesting that consumers' TDS results are only marginally influenced by the definition of dominance.

Practical Applications

TDS is being used increasingly by consumers, for sensory research both in academia and industry. This study demonstrates to users of the TDS method that the definition of dominance is unlikely to influence results when working with consumers. Furthermore, this study illustrates the capability of TDS using consumers for the sensory evaluation of food.

1 | INTRODUCTION

Real-life sensory perceptions involve a series of dynamic processes in the mouth, including structural or temperature changes, often accompanied by the dynamic release of volatiles and tastants (Albert et al., 2012). To provide a specific conscious temporal sensory effect of the stimuli, some food products are intentionally made; for instance, alternative sweeteners to provide quick disposal of taste, while others such as chewing gums, beers, or wines are developed to provide a delayed onset and subsequently stretched persistence of sensory experiences through multiple layers, flavor-filled grains, or cores. Inline, several sensory methods have been developed for this dynamic temporal sensory characterization, from the moment a product enters the mouth, throughout oral processing, and indeed after swallowing. Among all those methods, temporal dominance of sensations (TDS) is the most common, developed in the late 1990s at the "Centre Européen des Sciences du Goût" (Pineau & Schilch, 2015).

TDS is a multi-attribute method where participants select the most dominant attribute from a list of relevant attributes. TDS has been tested more extensively as a method with trained panelists. However, TDS can be performed with a relatively small amount of training and has potential with consumers as a time-efficient rapid profiling method because participants only consider selecting an attribute rather than scoring the intensity (Pineau & Schilch, 2015). However, the most

notable concern regarding the use of TDS with consumers (and TDS with trained participants) is understanding what the complex concept of dominance really means to the participant or how they conceptualize dominance. "Dominant" has been defined differently in the literature (Varela et al., 2018). Cadena et al. (2014) voiced a similar concern in their book chapter, "[sic] the definition of 'dominant' is not standard and differs among studies" (Cadena et al., 2014). A few others raised similar concerns about the lack of agreement among sensory scientists on the definition (Pierguidi et al., 2021; Schlich, 2017). It has been defined previously as "the most intense sensation" (Labbe et al., 2009), the one that "triggers the most the attention at a point in time" (Lenfant et al., 2009), "the most striking sensation" (Pineau et al., 2009), and "the new sensation popping up, and not necessarily the most intense." The majority of studies follow the definition proposed by Pineau and co-workers. Later, Pineau defined "dominant" in the Pangborn-2013 sensory science symposium as "the sensation that catches the attention at that time, a mixture of intensity and rising/new" (Pineau, 2013). Other studies followed the same route and defined it as the most intense sensation, the most striking sensation, or the new sensation popping up (Bruzzone et al., 2013; N. Pineau & Schilch, 2015; Rodrigues et al., 2016). However, the most common definition is "a sensation that captures assessor's most attention at a given time, which is not necessarily the most intense one".

Varela et al. (2018) were the first to identify how the differences in interpretation of the dominance concept could influence the TDS results of consumers through a series of qualitative studies. These differences can lead to heterogeneity in responses and potentially compromise the accuracy of TDS data. This research explained that the definition of *dominance* used with TDS is critical, and TDS results must be observed with some perspective of the definition used. This work also showed the most common reasons for selecting the dominant attribute by consumers. As stated previously, dominant sensations can be attributed to impressions that were the most "intense", the most "striking" (attracts attention), or the "popped up" sensation (change). However, no quantitative study has investigated the difference in TDS results by training consumers with these three different definitions of dominance. This study aimed to investigate the effect of definitions with three different groups of consumers having no prior TDS experience. Consumers were trained with a different definition of dominance: (a) TDS (The sensation that triggers the highest attention at any point in time); (b) TIS (The most intense sensation at any point in time); and (c) TCS (The sensation changing the most/new sensation popping up at any point in time). The same sensory experiment (apart from a different definition of dominance) was undertaken for three different groups of participants (three sensory sessions).

2 | MATERIAL AND METHODS

2.1 | Test materials and serving procedure

Four different commercial chocolate types, viz., Lindt Lindor milk block (50% cocoa), Lindt Lindor extra dark block (60% cocoa), Lindt Excellence 70% cocoa, and Lindt Excellence 85% cocoa (Lindt & Sprüngli, France), varying in cocoa and milk content were purchased from a local supermarket to provide a moderate range of the flavor and texture experience. Chocolate was stored at 21–22°C, and sensory testing was also undertaken at 21–22°C. The chocolate was prepared 30 min before the experiment and served on a paper plate. For convenience, chocolate pieces were cut according to the predefined size on the chocolate block: a whole Lindt Lindor piece (≈5.5 g) and a half of a Lindt Excellence piece (≈4.5 g). Duplicates of each chocolate were served (each participant tasted eight chocolate pieces in total; all served in a randomized order). Water, crackers, and a cup of water were used to cleanse the palate in-between each sample.

2.2 | Consumer selection

Consumers were recruited from students and staff of the University of Melbourne, through email, noticeboards, and websites. Group 1 (TDS session) comprised 45 consumers (Male = 12, Female = 33; 18–34 years of age), Group 2 (TIS session) comprised 49 consumers (Male = 18, Female = 31; 18–34 years of age), and Group 3 (TCS session) comprised of 48 consumers (Male = 8, Female = 40; 18–34 years of age). All consumers were fluent in English. Education background and nationality were not recorded. A coffee voucher was provided to participants as a reward after the study. Before starting, participants were instructed to read an information sheet and sign a consent form. All participants provided informed consent to participate. A list of major ingredients of chocolate was provided to participants in case of food allergies. This study was approved by the Human Ethics Committee of the University of Melbourne under Ethics Application 1,545,786.2.

To ensure no bias in the understanding of dominance, it was a requirement that none of the consumers had been involved in a temporal dominance of sensations study before, and participants could only take part in one of the three sessions (either TDS, TIS, or TCS). The alternative design option of working with a single group of consumers and getting them to undertake the task with all three definitions (a within-subject design) was considered but deemed an approach that would introduce too much of a carry-over effect from one dominance definition to another.

2.3 | Attribute list generation

Attribute generation was conducted via a small group discussion by the researchers involved in this study. The four chocolates were cut to the same serving size as the main study, and consumer-relevant terms were generated. Through consensus, selecting the most frequently quoted terms and eliminating confounding terms that described the same sensation, 12 attributes were selected as follows: bitter, sweet, dairy/milky flavor, melting, cocoa, powdery/dry, hard, chewy/tough, sticky, runny/fluid, soft, and vanilla.

2.4 | Training

All participants received an essential 20-min training before sitting in this study. Training sessions were consistent for all participants in all three sensory groups. The TDS, TIS, or TCS method and procedure were explained using a presentation. The only difference among the three sessions (TDS, TIS, and TCS) was the definition of "dominance" (Table 1).

2.5 | Experiment

All the data collection was carried out using RedJade© (RedJade Software Solutions, LLC, USA), through touch screen tablets (Samsung [18 in.], Korea). Participants used their fingers to operate the tablets, rather than a mouse, as recommended by Visalli and co-workers (Visalli et al., 2016). Participants were presented with the 12 attributes on the tablet screen as shown in Figure 1. All attributes were listed in a random order, but this order was always the same for a given person to assist them in locating the relevant attribute. Participants were also instructed to review the position of the attributes on the tablet before the evaluation. Firstly, participants put the chocolate sample into their mouths and simultaneously clicked the "start" button. Then, they were free to choose any attribute as their dominant chosen attribute based on their trained definition. If and when the dominant attribute changed, they would choose another new dominant attribute. This procedure continued until the sample was swallowed, at which point, they clicked the "stop" button. A 30 s break was given between samples, where participants were instructed to rinse their mouth with water and take a bite of cracker between each sample. They could choose as many attributes as they want during the evaluation, and an attribute could be chosen more than once for one sample. Participants did not have to choose all attributes if some attributes were not perceived. Table 2 summarizes the instructions for each method (TDS, TIS, and TCS) that participants could see on the screen above the attributes.

TABLE 1 The three definitions and descriptions of dominance used to train participants in this study

Sensory session	Definition
TDS (temporal dominance of sensation)	A sensation that triggers the most attention at a point of time (it could be the most intense, most unusual, most changing, and most striking sensation).
TIS (temporal intensity of sensation)	The most intense sensation at any point in time (intensity is the relative strength of a taste, flavor, or texture).
TCS (temporal change of sensation)	The sensation changing the most/new sensation popping up at any point in time. (change is different to intensity. Example: When listening to music, the sound bringing the biggest change to the melody may not be the loudest sound).

2.6 | Data analysis

2.6.1 | TDS curves

The raw data collected by RedJade© included the name of the dominant attribute, each point in time when an attribute was

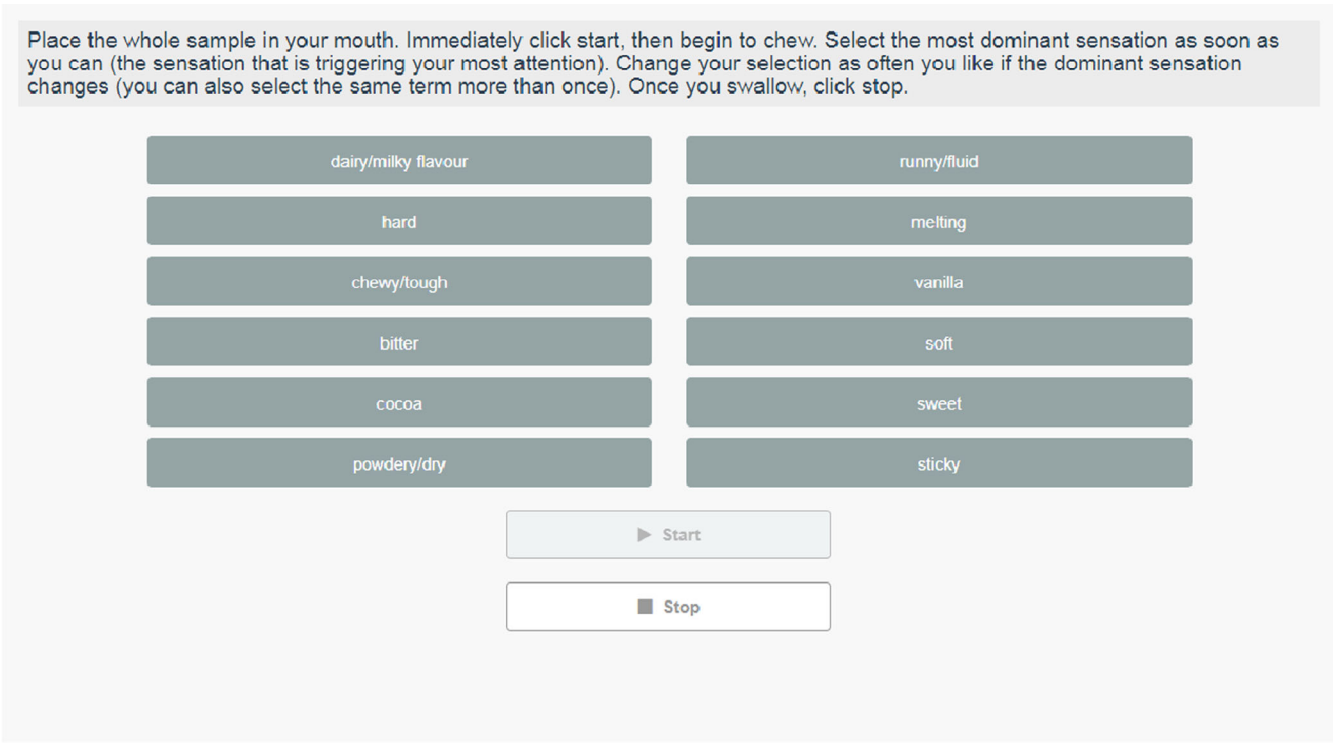

FIGURE 1 A snippet of the layout presented to the participants for selection of the attributes perceived dominant

TABLE 2 The instructions that consumers received in each sensory session

Sensory session	Instruction on screen above attributes
TDS (temporal dominance of sensation)	Place the whole sample in your mouth. Immediately click start, then begin to chew. Select the most dominant sensation as soon as you can (the sensation that is triggering your most attention). Change your selection as often you like if the dominant sensation changes (you can also select the same term more than once). Once you swallow, click stop.
TIS (temporal intensity of sensation)	Place the whole sample in your mouth. Immediately click start, then begin to chew. Select the most intense sensation as soon as you can. Change your selection as often you like if the most intense sensation changes (you can also select the same term more than once). Once you swallow, click stop.
TCS (temporal change of sensation)	Place the whole sample in your mouth. Immediately click start, then begin to chew. Select the sensation changing the most/new sensation popping up that point in time. Change your selection as often you like if the sensation of most change becomes different (you can also select the same term more than once). Once you swallow, click stop.

chosen as dominant, and the dominance duration of each selected dominant attribute (with a data capturing sensitivity of 0.001 s). To produce TDS curves, the standardized results (percentage selection of each attribute at every 5% standardized time interval) from RedJade© were exported to Microsoft Excel. Then, TDS curves were produced with a simple scatter plot with smoothed lines. Standardized time was used because the data collection period from start to stop (mastication period) differs between participants and between products.

2.6.2 | Chance and significance limit

To get more insight from the TDS curves, two lines representing the chance and significance limit were added to the graphs, calculated using the following formula below according to standard protocol in TDS studies (Pineau et al., 2009). The chance limit is defined as the dominance rate that an attribute can obtain *by chance*, while the significance limit is defined as the minimum value of the proportion that is considered as significantly ($p < .05$) higher than the chance limit, calculated from the confidence interval of a binomial proportion based on a normal approximation (Cadena et al., 2014).

$$\text{Chance limit}: P_0 = \frac{1}{P}.$$

$$\text{Significant limit}: P_s = P_0 + 1.645\frac{\sqrt{P_0(1-P_0)}}{n}$$

where P = the number of attributes; P_S = smallest significant proportion value ($\alpha = 0.05$); n = number of participants × replication

2.6.3 | Measurement of TDS behavior & attribute selection

To quantify differences in TDS behavior, a series of indicators were generated from the raw data including "time to the first attribute selection", "total duration time" (the duration from choosing "start" to "stop"), "the total number of attributes selected" (could be more than 12 in some cases, if attributes were reselected), and "the number of attributes used" (each unique attribute selected—this could be no more than a maximum of 12). TDS behavior indicators and dominance duration (s) of each attribute were statistically evaluated using mixed model ANOVA in SPSS (IBM, Version 23, USA). The within-subject factor represented the four chocolate products (Lindt Lindor milk block, Lindt Excellence 85% cocoa, Lindt Excellence 70% cocoa, and Lindt Lindor extra dark block), while the between-subject factor represented the three sessions using different definitions of dominance (TDS, TIS, and TCS).

2.6.4 | Session performance

The method followed to assess session performance (dominance definition) was developed elsewhere (Galmarini et al., 2017; Rodrigues et al., 2016). A mixed model MANOVA on TDS results [dominance duration (s) of all attributes: hard, cocoa, butter, dairy, melting, powdery, soft, sweet, vanilla, chewy, sticky, and runny] was applied to assess the effect of the session (dominance definition) and chocolate type, and the interaction between session and chocolate type. A subsequent MANOVA on TDS results [dominance duration (s) of all attributes] was then undertaken separately on each session to assess the session effect on product discrimination. Data analysis was performed in SPSS (IBM, Version 23, USA). A Principal Component Analysis (PCA) was also applied to interpret relationships between the sensory attributes of the chocolate samples and the three sessions. A product-attribute biplot was used for illustration of the PCA. Hierarchical Cluster Analysis (HCA) was performed using the Euclidean distance and the Wards linkage to categorize similar sample groups in the sensory and analytical results. Data analyses were performed using the XLSTAT (Addinsoft) statistical software version 2017.

3 | RESULTS

3.1 | TDS curves

Figures 2–5 display the dynamic profiles of the four chocolate types in three sessions using different definitions as attribute selection

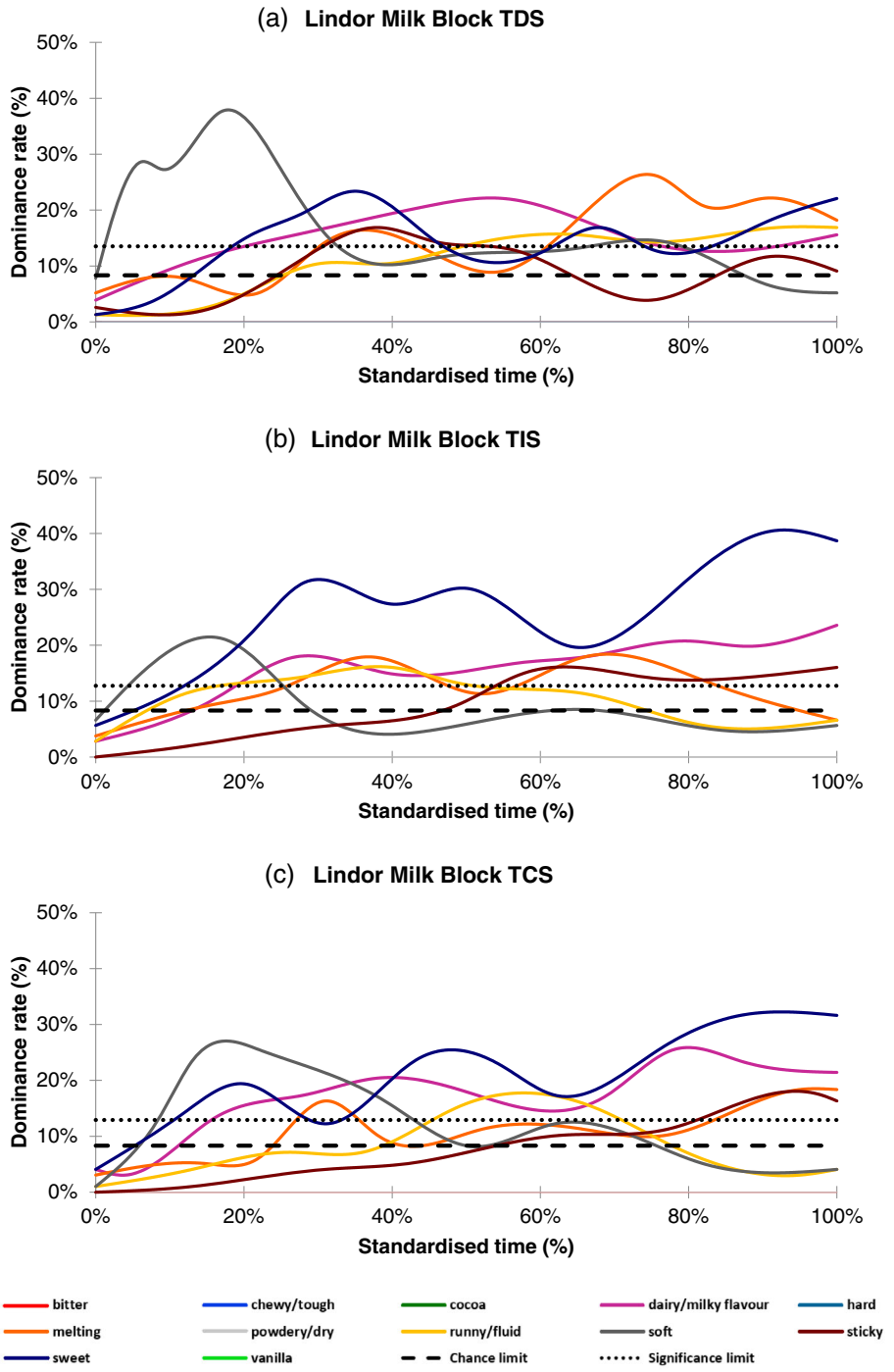

FIGURE 2 Above significance level curves for Lindt Lindor milk block (50% cocoa) chocolate sample. TDS (The sensation that triggers the highest attention at any point in time); TIS (The most intense sensation at any point in time); and TCS (The sensation changing the most/new sensation popping up at any point in time)

criteria (TDS, TIS, and TCS). Each curve demonstrates the evolution of the dominance rate of all attributes from the initiation of mastication ($t = 0\%$) until swallowing ($t = 100\%$).

3.1.1 | Lindt Lindor milk block (50% cocoa)

When mastication started, softness was the first attribute that seized assessors' attention, followed by sweet and dairy flavor. The onset of sweetness was seen delayed with the TIS and TCS definitions. TIS, defined as the most intense sensation, produced a curve where the onset of sweetness was quite earlier than TDS. In addition, it remained significantly dominant until the end of perception ($p < .05$). A similar trend was noted with the TCS definition.

3.1.2 | Lindt Lindor extra dark block (60% cocoa)

At first sight, one can clearly recognize that the overall signature of extra dark chocolate is very complex with overlapping attributes

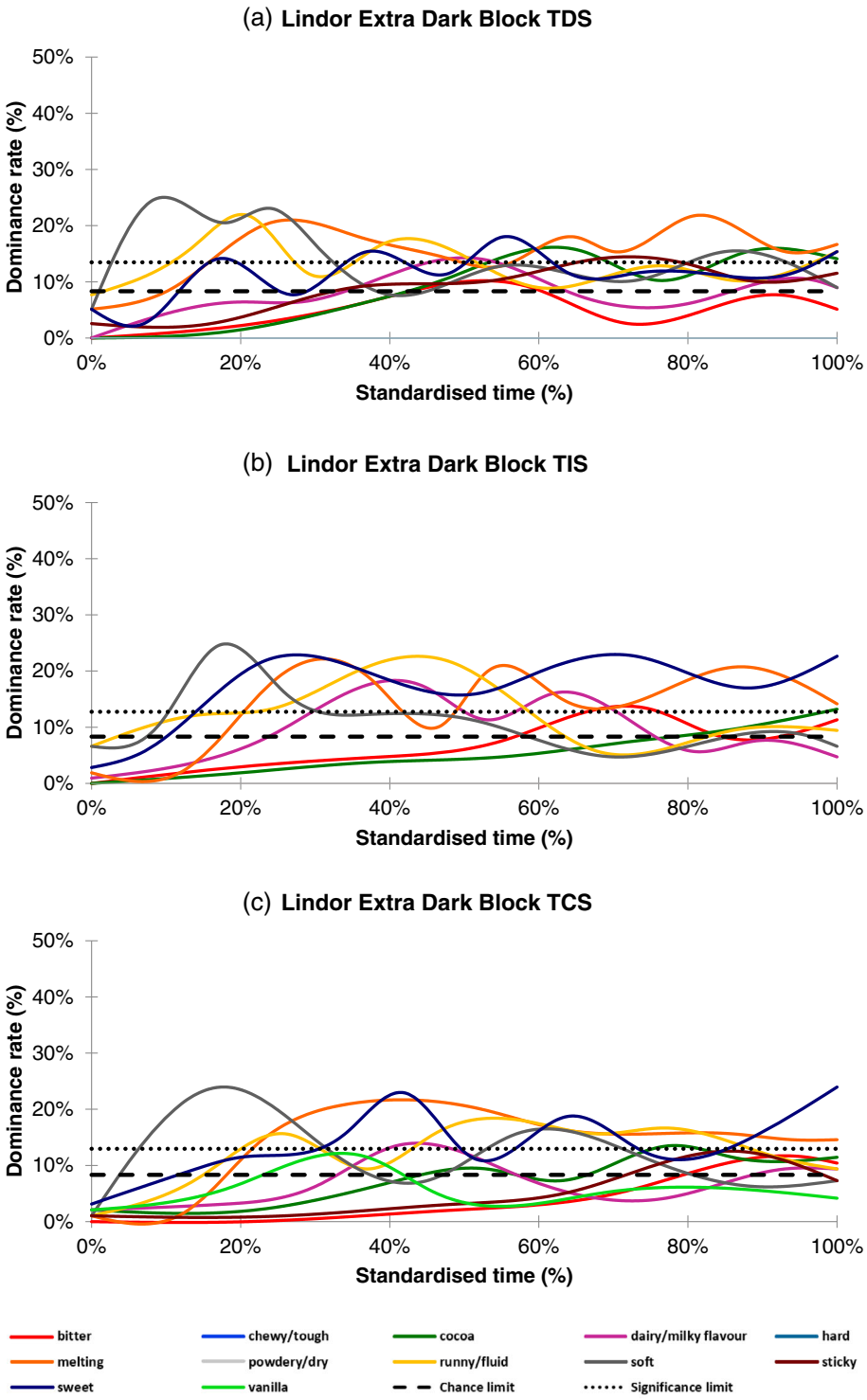

FIGURE 3 Above significance level curves for Lindt Lindor extra dark (60% cacao) chocolate. TDS (The sensation that triggers the highest attention at any point in time); TIS (The most intense sensation at any point in time); and TCS (The sensation changing the most/new sensation popping up at any point in time)

diffusing into each other at different periods to produce an intense web of subtleties (Figure 3). This complex structure of subtleties often helps fetch a premium over the plain "bound to get noticed" feature type (Cerulo, 2018), possibly attributed to a nondeclarative enculturation that could partly explain the higher cost of complexities. Softness was the first significantly dominant attribute ($p < .05$) in this sample, but unlike milk chocolate, this was often accompanied by other significant attributes. A more plateau structure of soft attribute emerged with the TIS definition as compared to the TDS and TCS definitions. As observed for texture with the Lindt Lindor milk block, the soft attribute was the most selected attribute at the early stages of mastication, before the runny/fluid and melting sensations emerged. The cocoa attribute was also selected at a significant rate ($p < .05$) in the middle and later stages of mastication for the Lindt Lindor Extra Dark Block. Compared with the Lindt Lindor milk block, the maximum dominance rates of the attributes were not more than 30% except for soft

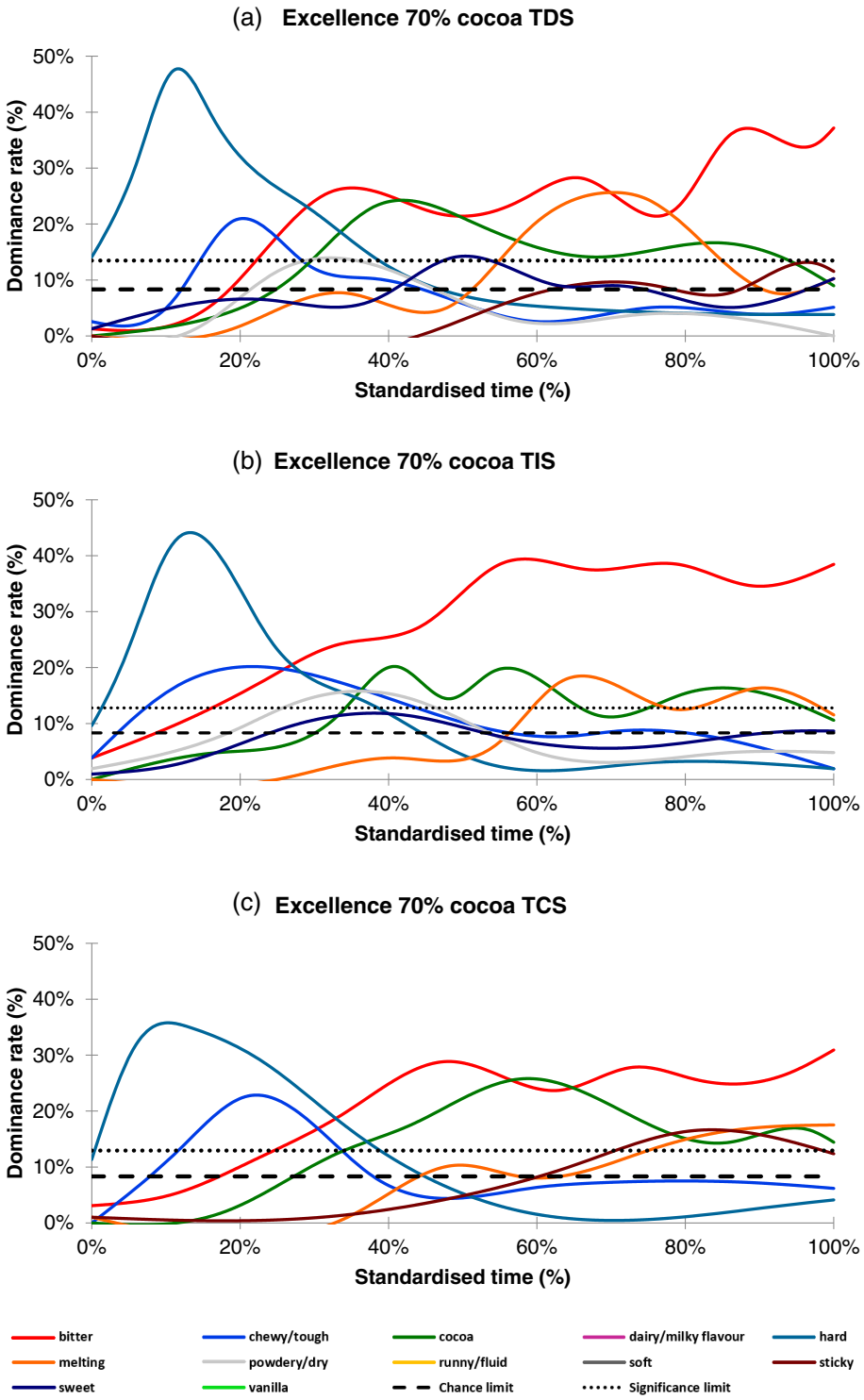

FIGURE 4 Above significance level curves for Lindt Excellence (70% cocoa) chocolate. TDS (The sensation that triggers the highest attention at any point in time); TIS (The most intense sensation at any point in time); and TCS (The sensation changing the most/new sensation popping up at any point in time)

attributes in the TCS session, which demonstrates more heterogeneity in the selection of attributes for this product.

3.1.3 | Lindt excellence 70% cocoa

The curves for Lindt Excellence 70% cocoa showed six attributes with a selection rate above the level of significance ($p < .05$): hard, chew/tough, powdery/dry, cocoa, bitter, and melting (Figure 4). At the early stages of mastication, hard and chewy/though were selected at the highest rates. This was then followed by high selection rates of bitter, cocoa, powdery/dry, and melting in the middle and later stages of the mastication sequence. General trends were similar across all three sessions. However, in the TIS session, the bitter attribute was the most intense sensation earlier in the mastication sequence and at a greater rate than in the TDS and TCS session.

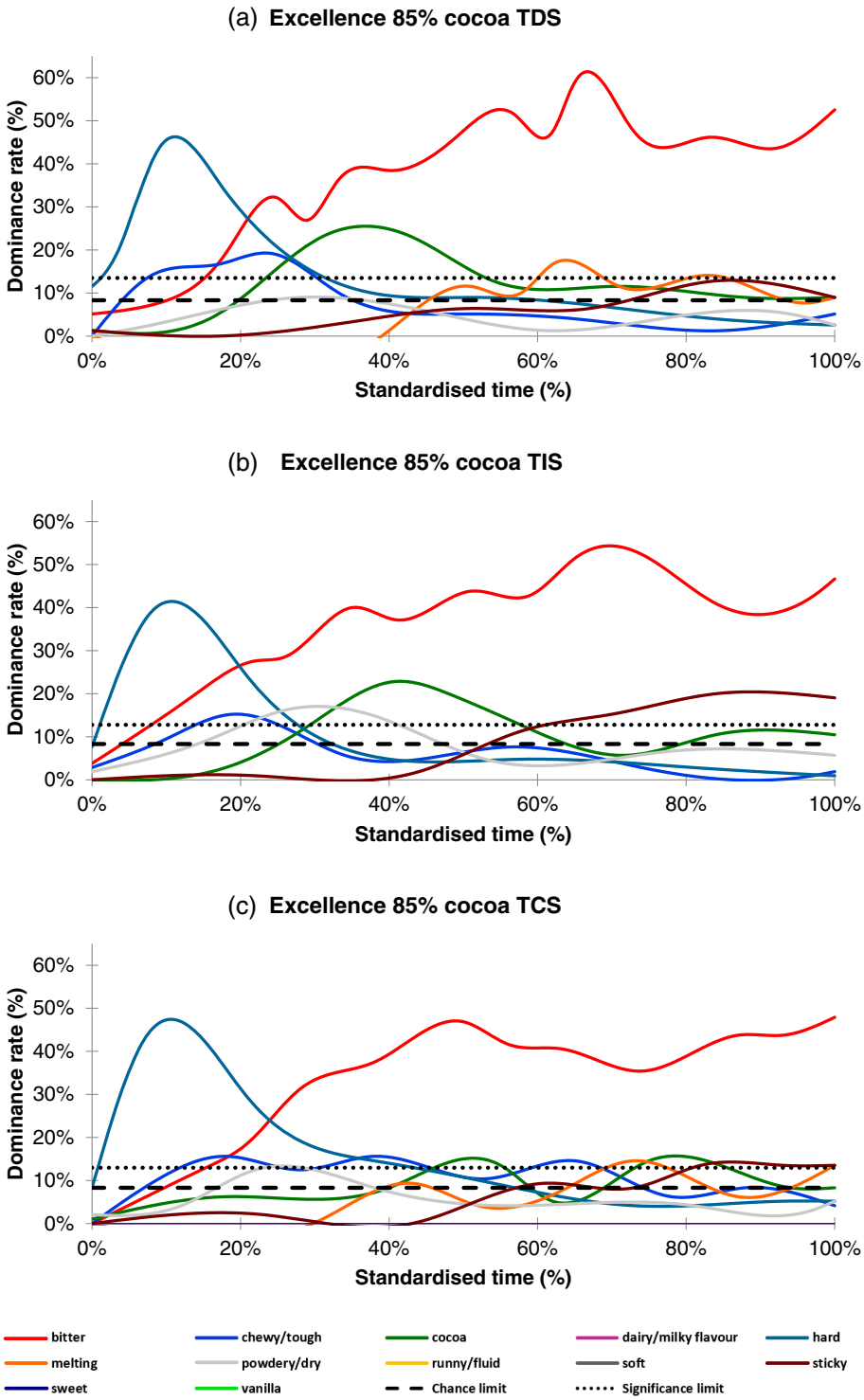

FIGURE 5 Above significance level curves for Lindt Excellence (85% cocoa) chocolate. TDS (The sensation that triggers the highest attention at any point in time); TIS (The most intense sensation at any point in time); and TCS (The sensation changing the most/new sensation popping up at any point in time)

3.1.4 | Lindt excellence 85% cocoa

Two significant attributes (hard and bitter) characterized the Lindt Excellence *85% cocoa* for all three sessions (Figure 5), where high selection rates of hard at the beginning of the mastication sequence were followed by high selection rates of bitter in the middle and latter stages of the mastication sequence. Other attributes selected at rates above the level of significance ($p < .05$) were chewy/tough, followed by powdery/dry, then cocoa, then melting and sticky (Figure 5). Trends are similar for all three sessions, but some differences can be noted. In particular, greater selection rates of hard can be seen in the TCS sessions than in the TIS and TDS sessions, and the selection rate of chewy/tough also sits above the significance level ($p < .05$) for a greater portion of time for TCS compared to TIS and TDS. The selection of cocoa was also greater for the TIS session than for the TDS and TCS sessions at the middle stages of the

mastication sequence. The selection of sticky was greater for the TIS session than for the TDS and TCS sessions at the later stages of the mastication sequence.

3.2 | TDS behavior

Table 3 shows the TDS behavior of subjects in three sessions with different definitions of "dominance" for four chocolate samples.

3.2.1 | Time to the first attribute selection

The mixed model ANOVA revealed that the time for the first attribute selection varied significantly (F [2,139] = 3.0; p = .054) between sessions (although the level of significance was marginal). Participants in the TCS session took longer than those in the TDS and TIS sessions to select the first attribute, although pairwise analysis did not demonstrate any significant differences (p > .05). There were no significant differences between chocolate types at the time of the first attribute selection (F[3,417] = 1.0; p > .05). There was also no significant interaction between the chocolate types and definition methods (F [6,417] = 0.5; p > .05).

3.2.2 | Total selection time

While total selection time was greater for the TCS session, there were no significant differences between the definition methods for the total selection time (F[2,139] = 2.3; p > .05) using the mixed model ANOVA. However, the total selection time was significantly different between chocolate types (F[3,417] = 104.9; p < .0005), where the total duration of attribute selection was longest for the Lindt Excellence 85% cocoa, followed by Lindt Excellence 70% cocoa and Lindt Lindor extra dark block, and was shortest for the Lindt Lindor milk block. There was no significant interaction between chocolate types and definition methods (F[6,417] = 1.2; p > .05).

3.2.3 | Total number of attributes selected

The mixed model ANOVA revealed that the main effect for sessions with different definition methods was not significant (F[2,139] = 1.1; p > .05). However, a significant main effect for chocolate types was obtained in the total number of selections ([3,417] = 3.4; p < .05). Most selections were made for the Lindt Excellence 85% cocoa. No significant chocolate types × definition methods interaction was observed (F[6,417] = 1.2; p > .05).

TABLE 3 Comparison of TDS behavior between TDS, TIS, and TCS sessions (mean ± SE)

	Lindor milk	Lindor extra dark	Excellence 70	Excellence 85	Average across products
Time to first attribute (s)					
TDS	5.31 ± 0.73	5.64 ± 0.54	6.09 ± 0.92	5.73 ± 0.84	5.69 ± 0.77
TIS	5.01 ± 0.41	5.69 ± 0.43	4.84 ± 0.49	5.62 ± 0.59	5.29 ± 0.49
TCS	7.38 ± 1.01	7.36 ± 0.99	8.43 ± 1.23	7.10 ± 1.16	7.57 ± 1.10
Average across sessions	5.91 ± 0.44	6.24 ± 0.40	6.47 ± 0.55	6.16 ± 0.52	
Total duration (s)					
TDS	33.20 ± 1.30	37.57 ± 1.84	43.97 ± 2.22	48.16 ± 2.26	40.73 ± 2.11
TIS	33.22 ± 1.71	37.09 ± 2.01	43.74 ± 2.42	46.99 ± 2.88	40.26 ± 2.41
TCS	37.89 ± 2.22	41.06 ± 2.61	51.29 ± 3.80	56.03 ± 3.90	46.57 ± 3.36
Average across sessions	34.79 ± 0.09[a]	38.58 ± 0.11[b]	46.37 ± 0.14[c]	50.42 ± 0.15[d]	
Number of attribute selections					
TDS	5.93 ± 0.51	5.80 ± 0.51	5.64 ± 0.45	6.09 ± 0.48	5.87 ± 0.49
TIS	5.58 ± 0.34	5.49 ± 0.36	5.53 ± 0.44	5.49 ± 0.44	5.52 ± 0.40
TCS	5.08 ± 0.31	4.84 ± 0.31	4.74 ± 0.31	5.47 ± 0.43	5.03 ± 0.34
Average across sessions	5.52 ± 0.02[a]	5.37 ± 0.02[a]	5.30 ± 0.02[a]	5.68 ± 0.02[b]	
Number of attributes used					
TDS	4.60 ± 0.21	4.59 ± 0.25	4.57 ± 0.25	4.42 ± 0.23	4.54 ± 0.23
TIS	4.31 ± 0.20	4.48 ± 0.21	4.31 ± 0.22	4.07 ± 0.24	4.29 ± 0.21
TCS	4.14 ± 0.21	3.98 ± 0.22	4.02 ± 0.22	3.97 ± 0.20	4.03 ± 0.21
Average across sessions	4.34 ± 0.01	4.34 ± 0.01	4.29 ± 0.01	4.15 ± 0.01	

Note: Different letters within a row denote a significant difference between chocolates for each parameter across all sessions (p < .05) (pairwise comparisons). No significant pairwise comparisons were obtained between training sessions across all products. n (TDS) = 45 consumers, n (TIS) = 49 consumers, n (TCS) = 48 consumers. TDS (The sensation that triggers the highest attention at any point in time); TIS (The most intense sensation at any point in time); and TCS (The sensation changing the most/new sensation popping up at any point in time).

3.2.4 | Number of attributes used

There were no significant differences between definition methods for the number of attributes used (F[2,139] = 1.6; p > .05) using the mixed model ANOVA for the effect of using different selection criteria and chocolate types. The number of attributes used was also not significantly different between chocolate types (F[3,417] = 2.4; p > .05), and no significant chocolate types × session interaction was observed (F[6,417] = 0.8; p > .05).

3.3 | Average dominance duration(s) of each attribute

Table 4 shows the average duration of each attribute between the three sessions (TDS, TIS, and TCS) across all chocolate types, and Table 5 shows the average duration of each attribute between the four chocolate types across all sessions.

3.3.1 | The effect of sessions (different definitions of dominance)

In terms of texture, the average dominance duration (s) of the attribute chewy/tough was significantly different between the three sessions (F[2,139] = 3.2; p < .05). Pairwise comparisons of three sessions further indicated that this attribute was selected significantly longer in the TCS session than in the TIS and TDS sessions (Table 4). However, no significant chewy/tough attribute was found between TIS and TDS in the average dominance duration (s). Furthermore, there was no significant interaction between chocolate types and definition methods (F [6,417] = 2.0; p > .05) for the chewy/tough sensation. For the attribute sticky, the average duration was not significantly different between the definition methods (F[2,139] = 0.7; p > .05); however, a significant interaction was observed between definition methods and chocolate types (F[6,417] = 2.6; p < .05). For the attribute soft, the effect of definition methods was significant (F[2,139] = 4.4; p < .05), where participants in the TDS session spent a long time on the soft attribute in the TIS session. A significant interaction for soft was also observed between definition methods and chocolate types (F [6,417] = 2.4; p < .05). The selection of the attribute hard also differed significantly between methods (F[2,139] = 3.0; p = .054) (marginally significant), and the pairwise comparisons further indicated that there was a significant difference between TCS and TIS sessions for attribute hard. In addition, a significant interaction was observed between definition methods and chocolate types for the attribute hard (F [6,417] = 2.6; p < .05).

In terms of the taste, the average dominance duration (s) of the attribute sweet was significantly different between the three sessions (F[2,139] = 3.4; p < .05), and this difference mainly resulted from the significantly longer selection time of sweet with TIS compared to that of TDS, which was revealed by the pairwise comparisons of the three sessions. Moreover, there was a significant interaction between chocolate types and definition methods for sweet (F[6,417] = 3.3; p < .05). All other attributes (Powdery/dry, bitter, melting, vanilla, cocoa, runny, and dairy) showed no significant effect on session type and no significant interactions.

TABLE 4 Differences between training methods in average dominance duration of attributes (s) across all products (mean ± SE)

	Dominance duration (s)		
Attributes	**TDS**	**TIS**	**TCS**
Powdery/dry	1.21 ± 0.45	1.72 ± 0.66	1.71 ± 0.53
Bitter	6.61 ± 1.40	8.43 ± 1.46	7.69 ± 1.67
Hard	3.04 ± 0.76^{ab}	2.49 ± 0.57^{a}	3.81 ± 0.89^{b}
Melting	4.12 ± 0.62	3.51 ± 0.55	4.54 ± 0.81
Vanilla	0.97 ± 0.45	0.55 ± 0.21	1.05 ± 0.58
Chewy/tough	1.98 ± 0.55^{ab}	1.75 ± 0.44^{a}	2.77 ± 0.68^{b}
Cocoa	3.73 ± 0.88	3.34 ± 0.85	3.60 ± 0.90
Sticky	2.41 ± 0.49	2.88 ± 0.57	3.21 ± 0.99
Soft	2.84 ± 0.62^{a}	1.73 ± 0.43^{b}	2.58 ± 0.58^{ab}
Sweet	3.17 ± 0.66^{a}	4.86 ± 0.89^{b}	4.00 ± 0.83^{ab}
Runny/fluid	2.58 ± 0.69	2.39 ± 0.44	2.45 ± 0.64
Dairy/milky flavor	1.96 ± 0.48	2.30 ± 0.56	2.61 ± 0.64

Note: Different letters within a row indicate a significant difference between training methods (p < .05). n (TDS) = 45 consumers, n (TIS) = 49 consumers, n (TCS) = 48 consumers. TDS (The sensation that triggers the highest attention at any point in time); TIS (The most intense sensation at any point in time); and TCS (The sensation changing the most/new sensation popping up at any point in time).

3.3.2 | Effect of chocolate types

Across all methods, a significant difference between chocolate products was observed for bitter (F[3,417] = 180.7; p < .005), sweet (F [3,417] = 85.3; p < .005), dairy/milky flavor (F[3,417] = 75.0; p < .005), cocoa (F[3,417] = 33.5; p < .005), powdery/dry (F [3,417] = 39.0; p < .005), hard (F[3,417] = 107.2; p < .005), chewy/tough (F[3,417] = 53.9; p < .005), runny/fluid (F[3,417] = 46.0; p < .005), soft (F[3,417] = 71.3; p < .005), vanilla (F[3,417] = 7.2; p < .005), and melting (F[3,417] = 10.7; p < .005). Sticky was the only attribute that did not show any significant effect on the chocolate types (F[3,417] = 1.0; p > .05) (Table 5).

3.4 | Session performance

3.4.1 | MANOVA

While through MANOVA, the effect of dominance definition was significant (p < .05), the effect of chocolate type was much stronger (p < .001) (Table 6). There was no significant interaction between the chocolate type and dominance definition (p > .05). Results,

TABLE 5 Differences between products in average dominance duration of attributes (s) across all training methods (mean ± SE)

Attribute	Product	Dominance duration (s)	Attribute	Product	Dominance duration (s)
Powdery/dry	Lindor milk	0.00 ± 0.00a	Cocoa	Lindor milk	0.56 ± 0.15a
	Lindor extra dark	0.17 ± 0.07a		Lindor extra dark	2.69 ± 0.35b
	Excellence 70% cocoa	2.66 ± 0.39b		Excellence 70% cocoa	6.26 ± 0.70c
	Excellence 85% cocoa	3.38 ± 0.44b		Excellence 85% cocoa	4.70 ± 0.51c
Bitter	Lindor milk	0.13 ± 0.08a	Sticky	Lindor milk	2.97 ± 0.32
	Lindor extra dark	2.2 ± 0.37b		Lindor extra dark	2.33 ± 0.29
	Excellence 70% cocoa	10.3 ± 0.76c		Excellence 70% cocoa	2.55 ± 0.56
	Excellence 85% cocoa	17.79 ± 1.09d		Excellence 85% cocoa	3.53 ± 0.43
Hard	Lindor milk	0.08 ± 0.04a	Soft	Lindor milk	3.84 ± 0.31a
	Lindor extra dark	0.39 ± 0.19a		Lindor extra dark	4.55 ± 0.41a
	Excellence 70% cocoa	5.94 ± 0.46b		Excellence 70% cocoa	0.70 ± 0.17b
	Excellence 85% cocoa	6.02 ± 0.52b		Excellence 85% cocoa	0.38 ± 0.10b
Melting	Lindor milk	4.13 ± 0.29b	Sweet	Lindor milk	7.39 ± 0.53a
	Lindor extra dark	5.33 ± 0.44a		Lindor extra dark	5.91 ± 0.49b
	Excellence 70% cocoa	4.00 ± 0.45b		Excellence 70% cocoa	2.52 ± 0.35c
	Excellence 85% cocoa	2.74 ± 0.32c		Excellence 85% cocoa	0.31 ± 0.13d
Vanilla	Lindor milk	1.59 ± 0.40a	Runny/fluid	Lindor milk	3.69 ± 0.38a
	Lindor extra dark	1.59 ± 0.40a		Lindor extra dark	4.59 ± 0.43a
	Excellence 70% cocoa	0.28 ± 0.10b		Excellence 70% cocoa	0.65 ± 0.14b
	Excellence 85% cocoa	0.28 ± 0.19b		Excellence 85% cocoa	0.96 ± 0.21b
Chewy/tough	Lindor milk	0.36 ± 0.11a	Dairy/milky flavor	Lindor milk	5.29 ± 0.38a
	Lindor extra dark	0.54 ± 0.13a		Lindor extra dark	2.82 ± 0.32b
	Excellence 70% cocoa	3.75 ± 0.39b		Excellence 70% cocoa	0.93 ± 0.26c
	Excellence 85% cocoa	4.03 ± 0.41b		Excellence 85% cocoa	0.15 ± 0.06d

Note: Different letters within a column indicate a significant difference between products for that attribute ($p < .05$). $n = 142$ consumers.

TABLE 6 Multivariate ANOVA (MANOVA) results across all dominance definitions

	Wilks' lambda	*F*-statistics	*p*-value
Product effect (chocolate)	0.125	21.980	<.001
Dominance definition effect (session)	0.739	1.782	.016
Product x dominance definition interaction	0.547	1.327	.064

TABLE 7 Multivariate ANOVA (MANOVA) results for each dominance definition (across all products)

	Wilks' lambda	*F*-statistics	*p*-value
TDS session	0.183	7.723	<.001
TIS session	0.141	10.279	<.001
TCS session	0.144	9.902	<.001

Note: TDS (The sensation that triggers the highest attention at any point in time); TIS (The most intense sensation at any point in time); and TCS (The sensation changing the most/new sensation popping up at any point in time).

therefore, indicated that while the dominance definition influenced the perceived sensations, the effect of the chocolate type on the results was greater.

Subsequent MANOVA on each dominance definition (Table 7) showed highly significant product discrimination ($p < .001$) for all three definitions (sessions). The TIS session had the lowest Wilks' lambda (highest F value and most significant); however, the TCS and then TDS sessions also showed similar results.

3.4.2 | PCA and cluster analysis

For all chocolate samples, PCA and Hierarchical Cluster Analysis (HCA) results are shown in Figure 6. The PC biplot explained 86.5% (PC1 = 75.9% and PC2 = 10.6%) of the total data variability considering all the sensory attributes (dairy, sweet, runny, soft, vanilla, melting, bitter, powdery/dry, chewy/tough, hard, and cocoa) altogether. The powdery/dry, bitter, hard, soft, and runny vectors (factor

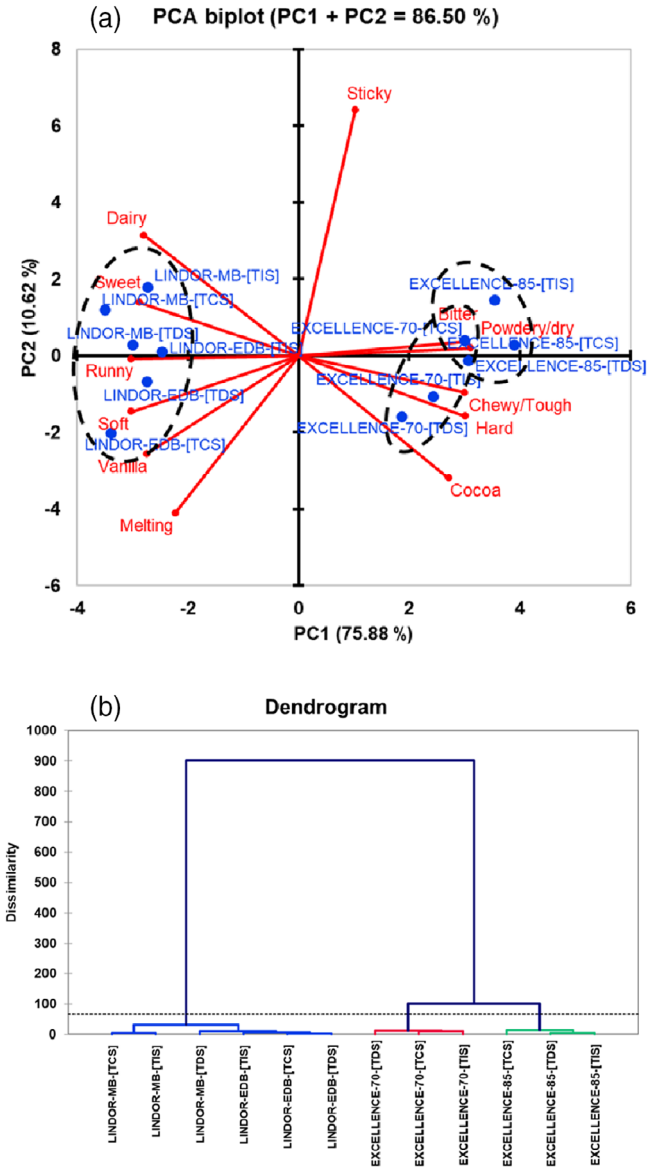

FIGURE 6 (a) Principal component analysis (PCA) biplot and (b) Cluster analysis visualizing treatments* (chocolate samples) and sensory attributes. *EDB = Extra dark block, MB = Milk block, 70 = 70% cocoa, 85 = 85% cocoa, TDS = The most attention-catching sensation, TIS = The most intense sensations, TCS = The most changing sensation

loadings = 0.95–0.98; data not shown) contributed largely to the discrimination of the chocolate samples in the PC1. On the other hand, the sticky vector (factor loading = 0.75) contributed largely to the discrimination of samples in the PC2.

From both analyses, the product type (Lindt Lindor vs. Lindt Excellence) had a greater effect in discriminating the samples than the training methods' effects (differences in panel performance due to dominance definition). In the PCA, there is a marginal separation of the samples in the PC1, which may be partially due to the training methods; however, this effect appears small.

The bitter vector was positively associated with powdery/dry and negatively associated with runny. The Lindt Excellence samples were associated with bitter, powdery/dry, chewy/tough, hard, and cocoa. On the other hand, the Lindt Lindor samples were associated with dairy, sweet, runny, soft, vanilla, and melting. Figure 6 shows the HCA of all chocolate samples considering all sensory variables. Three main cluster groups were formed: (a) all Lindt Lindor samples, (b) all Lindt Excellence 70% cocoa samples, and (c) all Lindt Excellence 85% cocoa samples.

4 | DISCUSSION

4.1 | Effect of dominance definition on attribute selection

In general, an overall comparison between the TDS, TIS, and TCS curves (Figures 2–5) demonstrates that the type of dominance definition between the three sessions (dominance, intensity, or change) did not have a large influence on the temporal results. Across all chocolate types, a similar evolution in attribute trends can be seen between all three methods at the earlier stages of mastication, middle stages of mastication, and later stages toward swallowing. Results suggest that despite the instructions given to consumers regarding dominance during the 20-min training (and the instructions regarding dominance located above the attribute list throughout testing on the tablets), the selection of attributes was an instinctive reaction in response to a sensation they perceive during the tasting. More specific analysis of session performance using MANOVA (Tables 6 and 7) and PCA (Figure 6) also supports this view, showing that the effect of dominance definition was small (although still significant) in comparison to the effect of chocolate type. Furthermore, all three sessions were able to discriminate chocolates to high levels of significance. While instructions or expectation has been shown to influence sensory perception across a range of food products (Deliza & Macfie, 1996; Olson & Dover, 1979), the effect of different dominance definitions on cognitive processing does not appear to have greatly influenced perception compared to the physiological effect of the chocolate.

However, some small differences can be seen between the three curves, and these differences were supported by subsequent analysis in terms of average attribute selection times (Table 4). TDS average attribute selection was similar across the three types of dominance definitions for 8 out of the 12 attributes but did differ for hard, soft, sweet, and chewy/tough between sessions. Significant interactions for average attribute selection were also observed between chocolate type and session type for sticky, soft, hard, and sweet.

When considering the TDS results as the control, pairwise comparisons of attribute selection revealed that TDS only differed with TIS for two attributes (higher selection of sweetness and lower selection of softness in TIS) and did not differ with TCS for any attributes. This may suggest that dominance, as traditionally defined in TDS, is more closely associated with attribute change/popping up than it is

with intensity, at least in the case of consumers. This result somewhat contradicts Varela et al. (2018) findings who reported different results in a qualitative study with chocolate when consumers were asked about the selection motivation of the dominant attribute; 34% reported that they selected it based on the most intense sensation, 20% as the most striking sensation, and 19% as the sensation popping up. However, in the present study, the magnitude of differences between sessions is very small compared to the difference observed between chocolates.

Results also showed similar trends between sessions in the behavior used by participants to undertake the TDS/TIS/TCS task (Table 3). The number of attributes used and the number of attributes selected were similar across all three sessions. Pineau et al. (2012), who analyzed 21 TDS studies, found that subjects usually use an average of four attributes to characterize a single sample, similar to the result across the three sessions for four chocolate types in this study (Table 5). The total duration of the sequence was also very similar between sessions. However, an effect approaching significance was observed for time to first attribute, where consumers in the TCS session took more time to select their first attribute. This suggests that when consumers put the product in their mouth and clicked start in the TCS session, they waited for a notable change from that initial experience before selecting an attribute. In the case of TDS or TIS, they were not waiting for that change.

4.2 | Effect of chocolate type on attribute selection

As expected, given the differences in cocoa content and structure between the four chocolates, TDS curves described large differences in the sensory properties between the chocolates (Figures 2–5). Subsequent statistical analysis also revealed significant differences in most attributes' average attribute selection time between the chocolates (Table 5). Numerous studies have demonstrated the ability of TDS to distinguish differences in sensory properties between food products (Hutchings et al., 2014; Labbe et al., 2009), including different chocolate formulations (Rodrigues et al., 2016).

In terms of TDS behavior, the total duration was longer in the Lindt Excellence chocolates, probably due to the harder texture (self-reported by the participants after the test), which induced a longer mastication time. The longest duration of the session was reported for the Lindt Excellence *85*, which also resulted in a greater number of attributes being selected. Variability between participants for all measurements of the TDS behavior (time to the first attribute selection, total selection time, the total number of attributes selected, and the number of the attribute used) was high (Table 3). Such variation between participants is commonly reported in TDS studies (Pineau et al., 2012).

4.3 | Recommendations for future research

Given the focus of this study on consumers, participants only received a small amount of training before undertaking the TDS, TIS, and TCS task: a 20-min session to describe the practicalities of using the method and the definition of dominance or intensity or change. Future studies should extend this by applying thorough training periods to produce three different groups of panelists, to understand the implications of different dominance definitions on the results of trained panels. While TDS works effectively with consumers, greater training (up to 5 hours) reduces the heterogeneity of selection and increases product discrimination (Hutchings et al., 2017). Conclusions from this study were limited by the type of product tested (chocolate)—future work should also consider testing different dominance definitions with other food categories. In particular, foods with more subtle and complex sensations would be worth testing; given that chocolate is a very intense product.

This study is also limited by the between-subjects design—each naïve (new to TDS) participant was assigned to only one definition of dominance. The disadvantage of this approach is that different people test each session. However, this design was implemented to ensure that no carry-over effect was possible from one definition of dominance to another. Had a within-subjects design been used (participants to take part in all three sessions), the way participants thought about dominance would be heavily influenced by their first session, affecting results in the second and third sessions.

5 | CONCLUSION

Results showed the three different training notions of "dominance" (most attention-catching, most intense, and most changing) did not noticeably influence general TDS data with consumers as all sessions showed similar TDS curves for all chocolates. MANOVA and PCA across all attributes showed that chocolate type had a much stronger influence on results than session type. Furthermore, all sessions also discriminated between chocolate types to highly significant levels. ANOVA showed that the average duration of attribute selection was found to be significantly different between definitions for four out of the twelve attributes: hard, chewy/tough, soft, and sweet. The number of attributes used and the TDS session did not influence the total duration of the assessment. However, some differences in attribute selection were also observed between definitions. Participants in the TCS session took longer to select their first attribute than those in the TDS and TIS sessions. Results suggested that TDS results with consumers are only marginally influenced by the definition of dominance.

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DATA AVAILABILITY STATEMENT

Research data are not shared.

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