# From consumption behaviour to sensory measurement: Sensory characterization of the perceived flavour complexity of a chocolate dessert experience

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## Highlights

- Perceived complexity of bi-layered chocolate desserts is related to the richness of perceived sensations
- The Sequential Profiling method (Methven et al., 2010) is adapted to characterize the full consumption experience of bi-layered chocolate desserts
- Most consumers eat bi-layered chocolate desserts in spoonfuls composed of both layers in varying proportions
- An eating protocol, based on consumers eating styles, is developed for bi-layered desserts

**Keywords**
Sequential profiling, Heterogeneous product, Perceived complexity, Observational study, Consumption behaviour

**Abstract**
The fresh dairy dessert category comprises a growing number of bi-layered products. These products can be considered as more complex than other dairy desserts because of their heterogeneity and the multiplicity of sensations they evoke. In this study, we set out to sensory characterize some bi-layered chocolate desserts and find the sensory determinants of their perceived complexity. To do this, we adapted the Sequential Profiling method to assess sensory attributes covering the full consumption of the dessert. This adaptation was based on the observation of consumers' eating styles during a first experiment. We observed that most consumers ate bi-layered chocolate desserts in spoonfuls composed of both layers, with different proportions of top and bottom layer. From these observations, we specified a standardized eating pattern representative of this behaviour. In a second experiment, seven commercial bi-layered chocolate desserts were evaluated by a panel trained to follow this eating pattern, and using the adapted sequential profiling. This evaluation showed the evolution of the sensory perception of bi-layered products from the first to the last spoonful. Perceived complexity data identified three groups of panellists based on their complexity scores. These groups matched three different ways to define 'perceived complexity' in a chocolate bi-layer dessert. We also observed that perceived complexity could be

related to the richness of the sensations perceived, and specifically to the maximum number of salient attributes and the fluctuation of dominant attributes during the sequence of spoonfuls.

## 1. **Introduction**

Perceived complexity is believed to be a relevant dimension in the development of food product preferences (Lévy, MacRae, & Köster, 2006). The perceived complexity of food products is often considered as a sensory property in itself (Palczak, Blumenthal, Rogeaux, & Delarue, 2019). In the literature, sensory complexity is associated with the number of perceived sensations (Bitnes, Ueland, Møller, & Martens, 2009; Lévy et al., 2006; Meillon et al., 2010; Pierguidi, Spinelli, Dinnella, Prescott, & Monteleone, 2019; Porcherot & Issanchou, 1998; Reverdy, Schlich, Köster, Ginon, & Lange, 2010; Ruijschop, Boelrijk, Burgering, de Graaf, & Westerterp-Plantenga, 2009; Weijzen, Zandstra, Alfieri, & de Graaf, 2008) and to the dynamic changes of sensations within a bite (Larsen, Tang, Ferguson, & James, 2016; Tang, Larsen, Ferguson, & James, 2017, 2016). These studies looked at complexity for only one bite or one sip of a product. However, perceived complexity should be characterized over the full eating or drinking experience (Kramer, 2012; Wang & Spence, 2018). Also, complexity is a collative property, depending both on the product's sensory properties and on the perceiver's experience and familiarity with the product (Lévy et al., 2006). Thus to fully understand perceived complexity, it is necessary not only to study the sensory characteristics of the product, but also to take into account each subject's perception at the individual level or at the very least in clustered subjects (Berlyne, 1971; Lévy et al., 2006).

In the past few years we have seen a growing number of fresh dairy desserts with multiple layers, textures or flavours, now representing 20% of the French fresh dairy market (Euromonitor International, 2018). Of these, a wide choice of bi-layered chocolate desserts is now available on the shelves of French retailers (6% of French dairy dessert innovations in the last 2 years (Database Innova, 2019)). In such products, each layer offers a different sensory profile, so offering more diversified and potentially more complex overall sensory experiences. These bi-layered chocolate desserts are mostly composed of layers with different tastes. The chocolate layer alone, in the range dark to milk, can bring a diversity of flavour sensations. The additional layer can contrast with other flavour sensations: caramel notes, vanilla notes, cream notes, etc. Finally, these desserts have layers with different textures (cream, coulis or mousse). We can expect flavour sensations offered by a chocolate mousse to be different from those offered by a chocolate cream. Thus, we hypothesize that these chocolate desserts, by bringing different flavour experiences, offer different levels of perceived complexity.

Providing a description of these complex overall sensory experiences is challenging. We would expect consumers to eat spoonfuls containing single separate layers, but also some spoonfuls made up of several layers or of stirred layers. To capture the sensory perception of such products, we need to know what type of spoonful to evaluate. In addition, the sequence of spoonfuls – from first to last – is likely to affect the overall sensory experience. For example, a spoonful from the chocolate layer followed by a spoonful of whipped cream may be perceived differently from whipped cream followed by chocolate, even if the layers are the same. To approach the whole sensory experience, it is thus important to characterize not only each layer separately, but also the perception resulting from the sequence of layers. Martin, Visalli, Lange, Schlich, & Issanchou (2014) proposed evaluating these types of products with a representative portion (spoonful) composed of the different layers. However, such a representative portion may be consumer-dependent. Consumption behaviours with heterogeneous products may differ from one person to another (Brown & Braxton, 2000). It thus made sense to first study consumer eating behaviour and to determine the different eating styles, and then develop a protocol adapted to the evaluation of such products. Finally, we know that eating behaviour may be influenced by the context of consumption (at home *vs*. restaurant *vs.* sensory booth) (Galiñanes Plaza, Delarue, & Saulais, 2018), suggesting that studies of consumer eating behaviour should allow for context.

The main aim of this work was to elucidate the sensory determinants of perceived complexity. To this end, we developed a methodology to sensory characterize heterogeneous products such as bi-layered chocolate desserts. Following Martin et al.'s (2014) proposal, and assuming that consumers differ in their eating styles, we first set out to identify what spoonful types consumers would naturally take when eating bi-layered desserts. We were also interested in the sequence of spoonfuls they followed to eat a whole cup. For this purpose, we first observed consumers' eating style when offered bi-layered desserts. To limit the influence of a potential chosen context, two different contexts were used to identify the eating styles. Depending on the observed patterns and their diversity, we then defined representative spoonfuls and sequences of spoonfuls for sensory evaluation. As stated above, the temporal sequence of spoonfuls may affect the sensory experience and the resulting perceived complexity. We thus decided to apply sequential profiling, which offers the possibility of assessing attributes over successive bites or sips and to analyse data at the individual level (unlike other methods such as T-CATA or TDS (Cadena, Vidal, Ares, & Varela, 2014)). Sequential profiling was developed to determine the perception of sensory attributes on repeated consumption of oral nutrition supplement samples over time (Methven et al., 2010). These products' specific remanence and sensory build-up need to be considered. This method gives good results with liquids (Withers, Barnagaud, Mehring, Ferris, & Thomson, 2016), and so should also work for semi-solid foods.

This paper is divided into two parts: an observational study followed by sensory characterization. The observational study was performed in two different contexts (meal context *vs*. sensory booth) with untrained volunteers. By contrast, the sensory characterization was done with trained subjects. Both experiments were carried out using commercial bi-layered chocolate desserts varying in complexity *a priori*. Products were chosen to express flavour differences during the full eating experience.

## 2. Materials and Methods

To address our aim, two successive studies were set up: an observational study and a sensory characterization study (Figure 1)

- Insert Figure 1 here -

### 2.1. Experiment 1: Observational study

#### 2.1.1. Products

Five chocolate bi-layered desserts sold in France were tested (Set 1 in Figure 2). These products were of the same brand but representative of the range of subcategories available on the market. One product from each available subcategory was chosen: *vanilla mousse on chocolate mousse*, *vanilla mousse on chocolate cream*, *chocolate cream on caramel cream*, *chocolate cream on caramel coulis*, and *chocolate cream on fruit coulis*. All these products are composed of a chocolate cream plus a top or bottom layer that can be a vanilla mousse (whipped cream analogue), a cream (with a different flavour but the same texture as the chocolate cream) or a coulis (topping sauce, more fluid than a cream). Products were stored at 4 °C and placed at room temperature one hour prior to the tasting session.

Figure 2. Products used in the two experiments

#### 2.1.2. Participants

Thirty-two untrained volunteers (25 women, 7 men, aged 23–26 years) participated in the study. All the participants were students at the AgroParisTech Center (Massy, France). They were regular consumers of dairy products and had no aversion for chocolate dairy desserts. The participants were randomly assigned to one of the two contexts tested.

#### 2.1.3. Contexts

Dessert eating behaviours were observed in two different contexts. The first (Context 1) consisted in a meal eaten in a test kitchen equipped with a dinner table and four dome cameras. The sixteen participants assigned to this context were randomly divided into four groups of four persons. Participants were invited for a meal, pretexting a focus group about pizzas during lunchtime. At the end of the focus group session, we offered them chocolate desserts as a reward. Participants were free to choose any chocolate dessert from the product set placed on the table.

The second test took place in sensory booths (Context 2). A different group of sixteen participants were asked to eat the chocolate dessert of their choice among the assortment and to rate their liking. They were specifically asked to eat all the product. Each sensory booth was equipped with one visible Gopro® camera.

In both contexts, participants had mineral water at their disposal with no specific instructions about rinsing their palate. They were also informed that they were being filmed during the session.

#### 2.1.4. Coding and data analysis

All the videos obtained were coded for the number of spoonfuls taken to eat all the dessert, the sequence of spoonfuls (time per spoonful and type of spoonful – ratio of bi-layered components) and activity during consumption (sip of water and discussion).

Data were analysed with chi-square and exact Fisher tests using XLSTAT 2017 software (Addinsoft, Paris, France).

### 2.2. Experiment 2: Sensory characterization

To come as close as possible to a natural consumption experience, the sensory evaluation was conducted at home.

As the evaluation sessions were to be done during the evening after dinner, and as the evaluation protocol implied consuming a whole cup of product, tasting one product at home each day appeared to be the best solution.
At the beginning of each week of evaluation, panellists came to the lab to get their set of products to evaluate them during the week at home.

#### 2.2.1. Products

Seven different French commercial bi-layered chocolate desserts were evaluated: two *vanilla mousse on chocolate mousse desserts* (Desserts MM1 and MM2), three *vanilla mousse on chocolate cream desserts* (Desserts MC1, MC2 and MC3), and two *chocolate cream on caramel cream desserts* (Dessert CC1 and CC2) (Table1). Products were either those used in Experiment 1 or variants of them (Figure 2). Variants were chosen to express flavour differences inside each category. Chocolate cream on caramel or fruit coulis were not included in Experimentation 2 because coulis offered a marked texture difference from the cream (very liquid coulis or presence of fruit pieces). Products were systematically presented blind. The general shelf life of these products is 30 days, allowing sensory stability during the two weeks of home evaluation.

- I sert Table 1 here -

#### 2.2.2. Participants

A group of fourteen subjects aged 24–58 years (3 men and 11 women, mean age 33.2 years) were selected for their motivation, their liking for chocolate dairy desserts and their availability to pursue a two-month study. They already had experience in sensory descriptive analysis for other product categories. They had to have an internet connection at home. They received compensation for their participation.

#### 2.2.3. Training

Prior to evaluation, a one-week pre-training period at home was organized to familiarize panellists with the product set and to generate sensory attributes. Each panellist thus received a coolbox containing the product set and a notebook. They were asked to eat each chocolate dessert, and to give their feedback using a paper form that included questions about taste and aroma. They were also specifically asked to pay attention to the evolution of sensations when eating each product. At the end of that week, a three-hour group session was organized for discussion and definition of a consensual list of sensory attributes (Table 2). The procedure of evaluation was also discussed with the panellists during that session.
The training period then consisted of 16 sessions lasting 30 minutes, conducted in sensory booths. In the first stage of training (six sessions), the spoonfuls made up of various dessert layer combinations were prepared before the session to help panellists evaluate attributes on these different types of spoonful. Different food products were used to calibrate the panel on sensory descriptors such as condensed milk, dark chocolate bars, caramel topping, etc. Then, during two sessions, they were trained to use a set eating pattern (as detailed in Section 2.2.4). The last eight sessions were used to train panellists in the evaluation of the five sensory attributes for the full pattern. Attributes were always evaluated on a 10 cm unstructured linear scale using digital tablets (Samsung Galaxy Tab

10.1”). In addition, four training sessions at home were also organized to validate panel performance at home.

- I sert Table 2 here -

#### 2.2.4. Evaluation

Using results from Experiment 1, we defined a representative, feasible and repeatable eating pattern (Figure 3). A sequence of 12 successive spoonfuls representative of the most frequently observed eating styles was first proposed to the panellists. We defined five types of spoonfuls to be sequentially evaluated. Each eating pattern had to start with one single top-layer spoonful and finish with two single bottom-layer spoonfuls. Intermediate spoonfuls had increasing ratios of layers: 2/3 top - 1/3 bottom, 1/2 top - 1/2 bottom, 1/3 top - 2/3 bottom. However, panellists commented that the amount of product in each spoonful was too small for a descriptive analysis. The sequence was therefore reduced to ten spoonfuls. Each spoonful comprised approximately 8 g of product. One eating pattern was developed for mousse-cream and mousse-mousse desserts and one for cream-cream desserts.

- I sert Figure 3 here -

To determine the temporal evolution of sensory attributes in this eating pattern, we conducted a descriptive analysis inspired by sequential profiling. Sequential profiling was developed by Methven et al. (2010) to profile the temporal evolution of sensations over eight repeat sips of oral nutrition supplements. For each sip, panellists had to evaluate five sensory attributes at three times after swallowing: $t = 0$, $t = 30$ s and $t = 60$ s. In this study the sequential profiling was adapted considering each spoonful as one ‘sampling occasion’ just after swallowing ($t = 0$). For each spoonful, panellists also rated five flavour attributes, in the same order (Table 2).

The chocolate desserts were tested monadically, in duplicate, following a balanced presentation order. One product was evaluated per day, at the end of dinner. Panellists were instructed to eat an unsalted cracker and to take a sip of mineral water (Evian) just before eating the test sample. Both were provided at the beginning of each evaluation session.

After they completed the sensory evaluation of a product, they were also asked to rate the level of complexity they perceived for it. This evaluation was performed on a 10 cm unstructured linear scale ranging from ‘not complex’ to ‘very complex’. We did not provide any definition of complexity, so that each panellist could rate it unprompted. To obtain insights into their understanding of complexity, we asked them to give their own definition of complexity during the training phase. Their individual definition was then displayed on the tablet during the evaluation at home.

All data were directly recorded on digital tablets using online EyeQuestion Software (version 4.6.6. Logic8 EyeQuestion software). To prevent any mistake during the evaluation at home, panellists had to enter a confirmation code printed on each product lid. We also recorded the time and the duration of each evaluation. Panellists complied with our instructions and completed their evaluations between 7 and 10 pm. On average, they took 7.2 minutes to evaluate each product.

#### 2.2.5. Data analysis

The statistical analysis of data was performed using XLSTAT 2017 software (Addinsoft, Paris, France) and RStudio® (Version 1.0.136).

Data from the sequential profiling were organized in a table with [product (7) x spoonful (10) x panellist (14)] rows and 5 columns (one for each attribute). The evaluation was duplicated, resulting in a total of 1960 observations.

These data were analysed using ANOVA. The panel performance was analysed using an ANOVA model with three factors (product, panellist, repetition) and their interactions. The product effect considers each product x spoonful pair and indicates whether the panel was discriminant ($p < 0.05$). Interactions were also used to determine whether panellists used the intensity scale between repetitions in a similar way (panellist x repetition), whether there was agreement among panellists (product x panellist) and whether panellists generated similar values between repetitions (product x repetition). Panellist performance was evaluated for panellist discrimination, agreement and repeatability.

Fisher’s Least Significant Difference (LSD) test was performed to know which spoonful × product combinations significantly differed from one another. To assess the sensory distances between the spoonfuls within and between each product, we ran a normalized principal component analysis (PCA) on the average table of the 70 observations (70 ProductSpoons) and five attributes.

Finally, perceived complexity was analysed at the panel level using a two-way ANOVA (with panellist and product as factor). *Post hoc* LSD tests were performed to determine which products significantly differed from another. Perceived complexity was also analysed after clustering. A hierarchical cluster analysis (HCA) was performed on panellists’ scores of perceived complexities to identify groups of panellists evaluating complexity in a similar way. ANOVA followed by an LSD test was done to determine which products significantly differed in perceived complexity in each group. All *post hoc* LSD tests were performed with a significance threshold set at 5%.

## 3. Results

### 3.1. Experiment 1: Observational study

All the proposed products were chosen at least once in each context. The *vanilla mousse on chocolate cream dessert* was the most frequently chosen. Regardless of the context, when eating their dessert, the clear majority of participants took different types of spoonfuls composed of bottom and top layers in different proportions (Figure 4). However, in the sensory booth, we observed two specific eating styles: one participant carefully ate the product layer by layer (Subject 26) and another participant first ate one spoonful of mousse and then stirred the product before eating it all (Subject 17). Although there is no proof, these behaviours might result from demand characteristics bias induced by the sensory booth context.

To further analyse the eating pattern, we evaluated three quantitative parameters (time for the consumption of the total cup, mean time per spoonful and number of spoonfuls) and one qualitative parameter (activity during consumption) for each context and each participant (Figure 4). The mean number of spoonfuls (13) and the mean time to eat all the dessert (1 minute and 55 seconds) were similar in both contexts. The mean time spent for each spoonful was significantly higher in sensory booths (8.5 seconds) than in the meal context (5.75 seconds). Contrary to the sensory booth context, the activity during the meal was not limited to eating the product, but also involved discussion. This was true for all the participants. Conversely, more participants drank water in sensory booths (seven participants out of sixteen) than during the meal (only one participant out of sixteen).

Evaluating the type of spoonfuls made by participants, we identified five types: spoonfuls with only vanilla mousse, chocolate cream or caramel cream, spoonfuls with both layers and spoonfuls with the dessert mixed.

- I sert Figure 4 here -

Surprisingly, participants' eating patterns were very similar, and most spoonfuls were composed of different layers. For mousse-cream and mousse-mousse desserts, we observed that in both contexts, about half of the participants started eating their desserts with spoonfuls of top vanilla mousse only. Likewise, about half of the participants finished their product with spoonfuls of bottom layer only (i.e. chocolate, cream or mousse). Similar patterns were observed for cream-cream desserts. Despite some individual features, eating styles were very close regardless of the dessert type.

Finally, it was interesting to observe from the videos that participants in sensory booths focused much more on their spoonfuls especially at the time of swallowing. By contrast, participants in the meal context were actively involved in their discussions and did not pay much attention to their dessert. The behaviour observed in the sensory booths may have been induced by demand characteristics and participants' awareness of good practices in sensory evaluation (Lawless & Heymann, 2010), and surely also because subjects had no-one else nearby to divert their attention.

### 3.2. Experiment 2: Sensory characterization and perceived complexity

We first analysed the performance at the panellist and panel levels. We discarded the results from two out of fourteen panellists because one was not discriminant and the other was not repeatable.

Regarding panel reliability (Table 3), a Rep*ProductSpoon effect was observed for vanilla only and was taken into account when interpreting the results ($F = 1.8$; $p = 0.002$). The homogeneity of the panel was determined by evaluating the interaction between ProductSpoon and Panellist for each attribute. Significant Panellist*ProductSpoon interactions were observed for the five attributes (chocolate, sweet, milk, caramel and vanilla). However, the good discriminating ability of the panel showed that disagreements between panellists were mainly due to differences in the use of the intensity scales. The detailed temporal analysis of the eating patterns (20 observations per Product*Panellist) is naturally conducive to more significant product x subject interactions compared to usual profiling data.

- I sert Table 3 here -

#### 3.2.1. Sensory characterization

After a two-way ANOVA with products and spoonful as main effects, we observed that for all attributes, the spoonful x product interaction was significant. This means that panellists perceived differences in sensory properties between the first spoonful and the last one. Results of *post hoc* tests revealed that for each product, panellists did not perceive differences between similar spoonfuls (e.g. two successive spoonfuls [1/3 mousse – 2/3 cream]) but between different types of spoonful (e.g. one spoonful [1/3 mousse – 2/3 cream] and one spoonful [1/2 mousse – 1/2 cream]) (LSD, $p < 0.0001$). *Post hoc* tests also revealed no significant differences between mousse-mousse products for the same spoonfuls or between mousse-cream product for the same spoonfuls. But cream-cream products were perceived to be significantly different (LSD, $p < 0.05$).

The PCA of the average descriptive data shows three groups of products: mousse-mousse products, mousse-cream products and cream-cream products (Figure 5). To gain a better understanding of the sensory evolution between spoonfuls, we grouped spoonful types after checking they were not different in any of the attributes. This allowed us to draw 'sensory paths' relating the different sequences of spoonful types on the factorial map. The grouped spoonful types are represented in Figure 5 with spoonful icons, and connected to each other with arrows to underline the temporal evolution.

We observe that mousse-mousse products and mousse-cream products had very similar sensory paths. These sensory paths were linked to a sensory evolution from milk and vanilla to chocolate and sweet. Conversely, cream-cream sensory paths were mainly characterized by their caramel note.

- I sert Figure 5 -

In Figure 5, four points (marked with an asterisk) represent spoonfuls composed of identical layers, although they belonged to different products: two vanilla mousse spoonfuls were from the MC1 and MM1 products, and two chocolate cream spoonfuls originated from MC1 and CC2. It is interesting to note that the two vanilla mousse spoonfuls are very close on the map, showing that panellists perceived these spoonfuls similarly. On the contrary, the two chocolate cream spoonfuls were not perceived identically, even though they were made up of the same chocolate cream. This difference could be explained by the different temporal experience: starting with a spoonful of chocolate cream does not result in the same sensory perception as finishing with a spoonful of chocolate cream. Nevertheless, we cannot rule out the possibility that the caramel cream flavour diffused into the chocolate cream, giving it an additional caramel note in the CC2 product.

If we look at distances on sensory paths, we observe that mousse-mousse products and mousse-cream products have a longer sensory path than cream-cream products. We can also underline that for mousse-mousse and mousse-cream products, the distances between vanilla mousse spoonfuls and others are greater. This highlights the fact that the evolution of sensory perception during the eating episode was more marked for the mousse-mousse and mousse-cream products. This may result from texture contrasts across the layers, whereas the cream-

cream products are more homogeneous in terms of texture.

### 3.2.2. Perceived complexity

Perceived complexity was first analysed at the panel level. We observed a significant difference between products using ANOVA ($p < 0.05$). Three groups of products were identified (LSD, $p < 0.05$) (Figure 6). CC1 and CC2 appear to be more complex and MM2, MC1, MM1 and MC2 less complex.

- I sert Figure 6 here -

However, complexity, which is a collative property, should be analysed at the individual level (Levy et al., 2006). Thus a hierarchical cluster analysis was performed on panellists' scores of perceived complexities. We identified three classes of panellists who evaluated product complexity in a similar way (Figure 7). A two-way ANOVA with group, product and group x product effects was performed on perceived complexity scores to check differences in perceived complexity scores between products and between groups. The group x product interaction was significant ($p < 0.05$), meaning that groups had different points of view on products' perceived complexity. The ANOVA for each cluster of panellists revealed that the product effect was significant for Clusters 1 and 2. Results of the Fisher LSD test showed that in Cluster 2, products fell into two clear categories: products with a high perceived complexity (CC1 and CC2) and products with a low perceived complexity. In Cluster 1 product MC3 had the highest perceived complexity, with no clear difference between the others. For both Clusters 1 and 2 CC1, CC2 and MC3 were the products with the highest perceived complexity (Figure 6).

- Insert Figure 7 here -

Interestingly, the definitions of complexity given by each panellist were close within each cluster. Panellists in Cluster 3 referred to 'the number of sensations perceived' (aroma, taste, texture, or layers), whereas panellists in Cluster 2, focused on the sensory evolution during consumption, and panellists in Cluster 1 linked product complexity to the 'difficulty identifying sensations characterizing the product'.

### 3.2.3. Relationship between perceived complexity and sensory characterization

The collative nature of complexity requires an analysis at the individual level. Sensory complexity can be related to the richness of perceived sensations brought by the product as a whole or from the evolution of sensations during the eating episode. Complexity could thus be considered for each spoonful separately (i.e. total number of different sensations perceived) or for the whole eating episode with a focus on the sequence of sensations. To transcribe and quantify these two notions, we defined two criteria for analysing individual data. These criteria are based on individual descriptive data: **the maximum number of salient attributes** (Criterion A), and **the fluctuation of dominant attributes** over the sequence of spoonfuls (Criterion B) (Figure 8).

An attribute was defined as 'salient' when its intensity was rated above a fixed threshold set at 20% of the intensity scale. To estimate the **maximum number of salient attributes** for each product (all spoonfuls considered) we counted for each spoonful the number of salient attributes. The maximum number of attributes over all 10 spoonfuls was kept as Criterion A for that given product. Theoretically, Criterion A could thus range from 0 to 5.

An attribute was defined as 'dominant' when its intensity was higher than the other four attributes. The **fluctuation of dominant attributes** was based on the relative intensity of the attributes over the whole sequence of spoonfuls. Thus only one attribute could be dominant for each spoonful. Theoretically, Criterion B could thus range from 1 to 10.

- Insert Figure 8 here -

Criteria A and B were calculated for all panellists and all products. Pearson correlation coefficients were calculated (for each panellist) between scores of perceived complexities and scores obtained for Criteria A and B (Table 4). A threshold of 0.1 was chosen considering the type of data used.

- I sert Table 4 here –

Results for Criterion A showed a significant correlation with perceived complexity for ten panellists out of twelve. For all of them, the greater the number of salient attributes, the more complex they perceived the product to be. For Criterion B, fluctuation of dominant attributes related positively to complexity for nine out of twelve panellists. Thus the richness of perceived sensations in a spoonful or during the whole eating episode seems to have had an impact on perceived complexity for most of the panellists. It is of note that panellists for whom no such relationships were observed in fact did not perceive any differences between the products in terms of complexity. They are all clustered in Group 3.

## 4. Discussion and conclusion

The adaptation of the Sequential Profiling developed by Methven et al. (2010) proposed in this article allowed the evaluation of a full eating experience. It highlighted the evolution of key sensory attributes during the consumption of a whole cup. The sequential profile revealed a clear sensory discrimination between spoonfuls and enabled us to discern sensory paths for a given product, from the first bite to the last one. We adapted the method to increase the number of spoonfuls, which did not complicate the sequential profiling technique and was easily understood and performed by trained sensory panellists. Nevertheless, the relatively small number of attributes (five in this study and discussed below) did not allow discrimination of all products. In addition, mousse-mousse products and mousse-cream products had very similar sensory paths: from *milk* and *vanilla* to *chocolate* and *sweet*. Conversely, cream-cream sensory paths were mainly characterized by the evolution of the *caramel* note. In a recent study, Withers et al. (2016) adapted the sequential profiling to manage more sensory attributes. Their results show that increasing the number of attributes to ten helps better discriminate samples. However, increasing the number of attributes also drastically increases the total time needed to complete the profiling study (Withers et al., 2016).

It should be emphasized that starting with an observational study brings a sensory characterization closer to a potential eating behaviour. Observing consumers helps us identify different eating styles and build our evaluation protocol on these observations. There was no available knowledge on consumers' behaviour with multi-layered products. Only one recent study observed that consumers can be categorized according to their mouth behaviours (crunchers, suckers, smoothers and chewers) involving different sensory perceptions (Jeltema, Beckley, & Vahalik, 2016). Like Jeltema et al., 2016, we observed different eating styles affecting sensory perceptions. The relative proportions of the different eating styles in the population of consumers would be interesting to determine with a larger and more representative population. For such a study, attention should be paid to context (including an instruction evaluation task) to limit demand characteristics. For example, we observed that in the meal context, subjects ate faster (5.75 *vs.* 8.5 seconds) and paid little attention to their desserts. Given that these desserts are eaten after dinner, it would be interesting to allow for subjects' satiety, which can influence consumption behaviour. We know, for example, that the time taken to eat a whole portion will increase with the level of satiety (Duncan, Bacon, & Weinsier, 1983).

From a sensory methodology standpoint, it was also of interest to re-evaluate the temporal eating pattern in regard to temporal sensory methodologies. In particular, the time to eat a spoonful. Our results show that participants ate a spoonful in 7.3 seconds on average (and eating the whole dessert took less than 2 minutes). This time frame is very different from the evaluation time imposed during more usual descriptive dynamic methods for dairy products. For example, task duration imposed for the evaluation of one spoonful in TCATA can range from 30 to 45 seconds (Alcaire et al., 2017; Ares et al., 2015; Castura, Antúnez, Giménez, & Ares, 2016; Esmerino et al., 2017) and in TDS from 45 to 90 seconds (Ares et al., 2015; Bouteille et al., 2013; Esmerino et al., 2017; Morais, Pinheiro, Nunes, & Bolini, 2014). Furthermore, with these methodologies, participants are often asked to eat the product in a specific way, to keep the product in their mouth and to swallow at a specific time for standardization purposes (Lawless & Heymann, 2010). All these methodologies were obviously designed to ensure accuracy of measurement (Cadena et al., 2014), but they may differ from what consumers perceive during a real eating episode.

Regarding the perception of complexity, we observed different clusters of perception. One group did not report any difference in complexity between products, while the other two groups perceived differences, but for some product types only. This illustrates the collative nature of complexity, and supports Lévy et al.'s view that no two subjects have the same perception of complexity (Lévy et al., 2006). In addition, we noted that groups with similar complexity scores were composed of panellists using a close underlying notion to define perceived complexity. Some referred to the 'number of sensations perceived', which is the most widely used definition in the literature (Bitnes et al., 2009; Lévy et al., 2006; Meillon et al., 2010; Porcherot & Issanchou, 1998; Reverdy et al., 2010; Ruijschop et al., 2009; Weijzen et al., 2008). Sensory evolution during consumption was used by three panellists, and is also mentioned by some authors (Larsen et al., 2016; Tang et al., 2017, 2016). Lastly, some panellists defined complexity as the 'difficulty identifying sensations or characterizing the product'. This notion is also used in some studies on aroma and taste complexity (Lévy et al., 2006; Meillon et al., 2010; Porcherot and Issanchou, 1998;

Ruijschop et al., 2009). All these approaches refer to the sensory dimension of complexity (Palczak et al., 2019). It is interesting to note that the emotional dimension ('level of surprise') was also used by one of our panellists, which echoes Reverdy et al.'s study on the complexity of hot dishes (Reverdy et al., 2010).

In this work, perceived complexity was evaluated on a linear scale ranging from 'not complex' to 'very complex'. Each panellist was free to develop their own definition of complexity during the training period. This possibility was appreciated by panellists, as it left them some freedom in their evaluation. In the literature, measures of perceived complexity are extremely diverse. Direct evaluation of complexity on a scale is the most widely used technique (Giacalone, Duerlund, Bøegh-Petersen, Bredie, & Frøst, 2014; Lévy et al., 2006; Meillon et al., 2010; Porcherot & Issanchou, 1998; Schlich, Medel Maraboli, Urbano, & Parr, 2015; Soerensen, Waehrens, & Byrne, 2015; Stolzenbach, Bredie, Christensen, & Byrne, 2016; Sulmont-Rossé, Chabanet, Issanchou, & Köster, 2008; Weijzen et al., 2008). Nevertheless, none of these studies allowed participants to spell out their own definition of perceived complexity, although two papers asked their participants to answer the question: "What characteristics did you consider in your evaluation of the complexity?" after they had completed the evaluation of complexity (Marcano, Morales, Vele-Ruiz, & Fiszman, 2015; Pierguidi et al., 2019). In both articles, generated terms helped the authors to understand and discuss what sensory characteristics are considered by consumers to judge complexity.

Despite the differences in the notions underlying perceived complexity, analysis of complexity scores at the individual level provided some common and insightful findings. Perceived complexity of bi-layered chocolate desserts seems to be impacted by the richness of sensations perceived. These sensations can be perceived for one spoonful or across the whole eating episode. The two criteria we used transcribe these notions: the number of salient attributes and the fluctuation of dominant attributes. The link between perceived complexity and the richness of sensations perceived could be expected. In their study on perceived complexity of wine, Meillon et al. (2010) also showed that complexity scores increased with the number of perceived aromas. They also related complexity to the superimposition of sensations along a timeline, which we did not assess in the present study.

It should be stressed that in this study, we limited the number of sensory attributes to five flavour attributes to limit the time of evaluation per spoonful. We decided to focus the sensory characterization of perceived complexity only on flavour evolution because products were chosen to express different flavour sensations. It would thus also be of interest to extend the study to the evaluation of texture.

Overall, our results show that evaluating product complexity requires dynamic, detailed measurements of perceived sensory characteristics. Future developments in dynamic sensory methods will need to find the right balance between the necessary accuracy of the measurement and its validity in relation to consumer behaviour. In addition, we emphasize that although this study was conducted with a small number of trained panellists, it supports the idea that complexity is a collative property. The measurement of complexity itself should therefore consider the diversity of participants' perceptions. Future experiments involving untrained consumers would be needed to further explore that diversity.

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Figure 1. Study process

Figure 2. Products choice for Experiments 1 and 2

Figure 3. Eating patterns developed to evaluate bi-layered products

Figure 4. Eating patterns observed in a meal context (A) and in sensory booths (B) for the 32 participants.

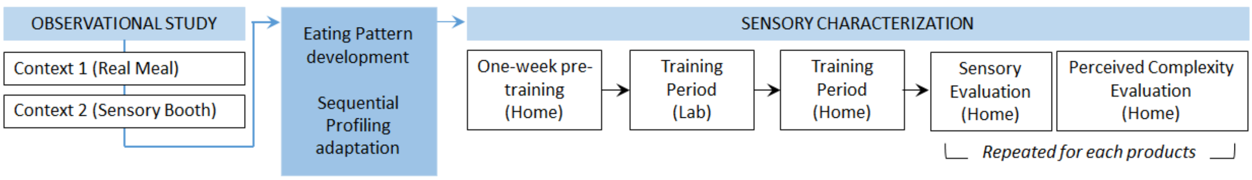
Figure 5. Representation of the products of the PCA performed on the table of averages of the assessors by ProductSpoon and by descriptor. Mousse-mousse points are in red, mousse-cream points are in brown while cream-coulis points are in yellow. Four sensory paths are drawn with black arrows and with spoon icons. Asterisks indicate spoons composed of identical layers.

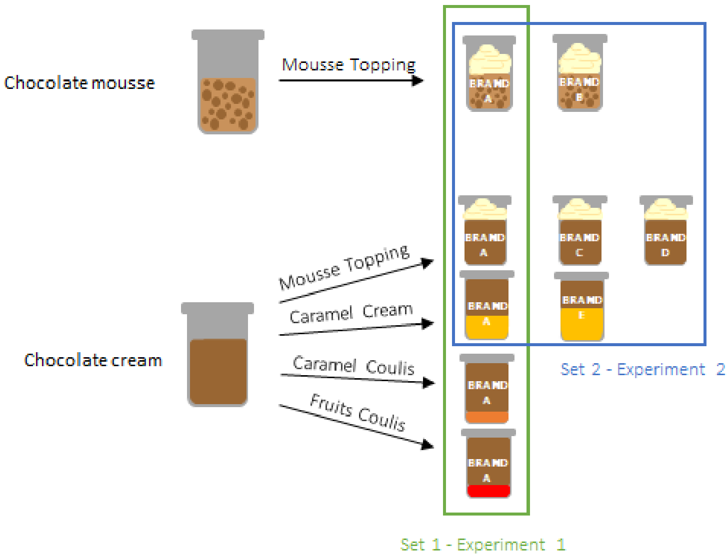
Figure 6. BoxPlots of perceived complexity for each product. Boxplots with different letters differ significantly at $p<0.05$ (LSD test)

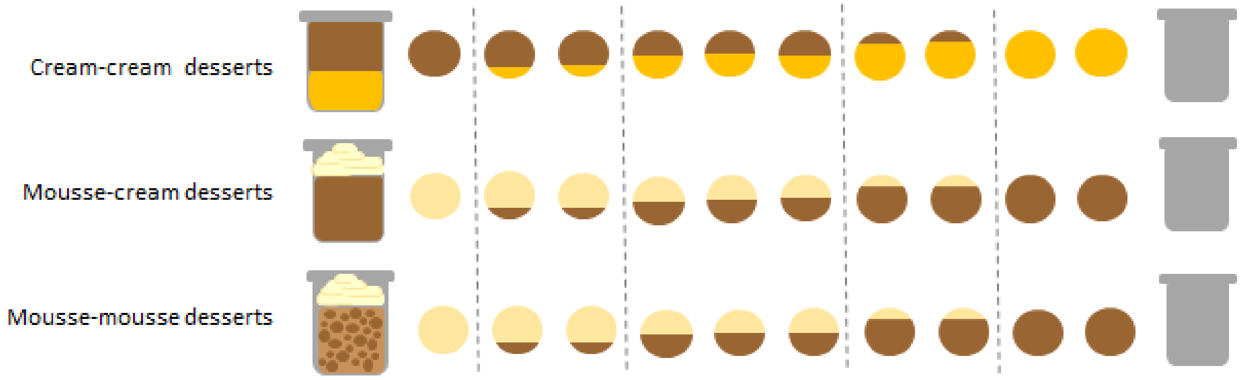
Figure 7. Results of hierarchical cluster analysis on normalized perceived complexity scores with average scores of perceived complexities for each cluster and each product. For each cluster, definitions of perceived complexity given by panellists and used for their evaluation.

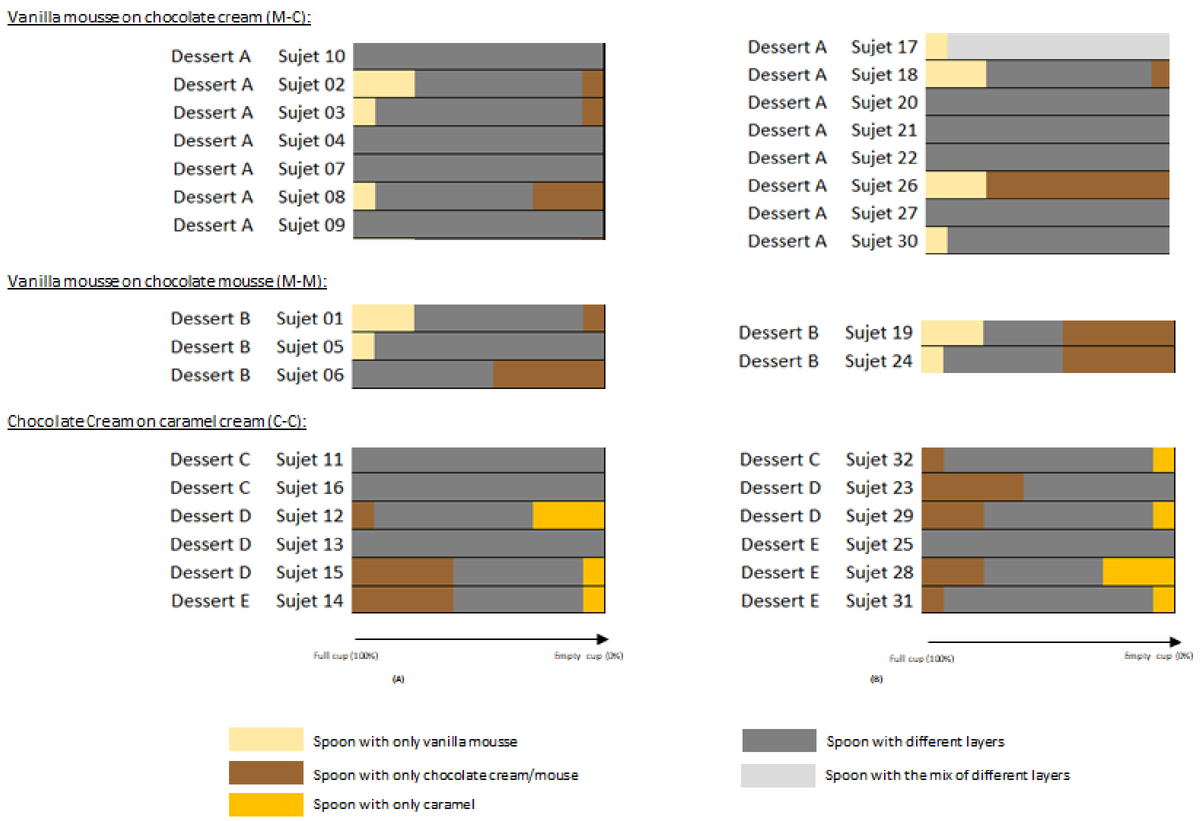
Figure 8. Example extracted from panellist 6 for the MC1 and CC2 products. Panellist 6 evaluated the perceived

complexity at 0.5 for MC1 product and 9.7 for CC2 product. On the left-hand side, Criterion A (the maximum number of salient attributes) is 3 for MC1 and 4 for CC2. On the right-hand side, Criterion B (the fluctuation of dominant attributes) is 2 for MC1 and 4 for CC2.

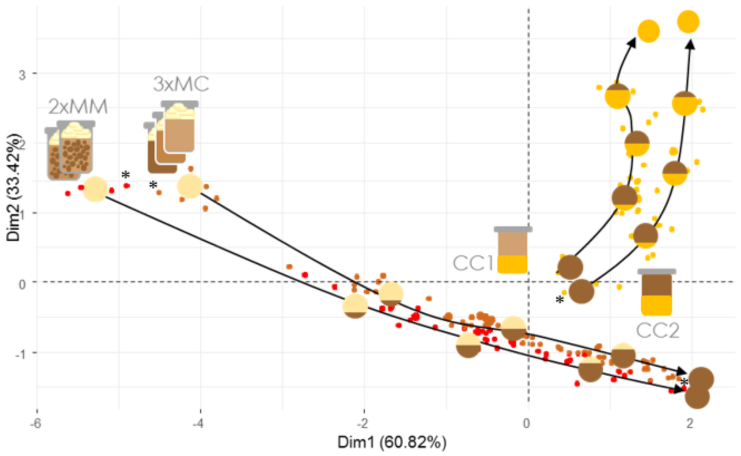


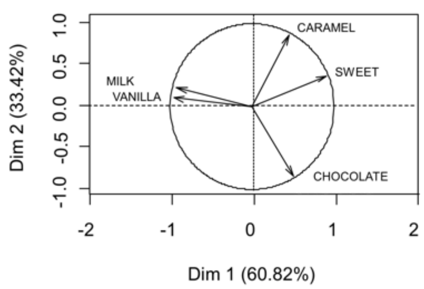

Cream-cream desserts
Mousse-cream desserts
Mousse-mousse desserts



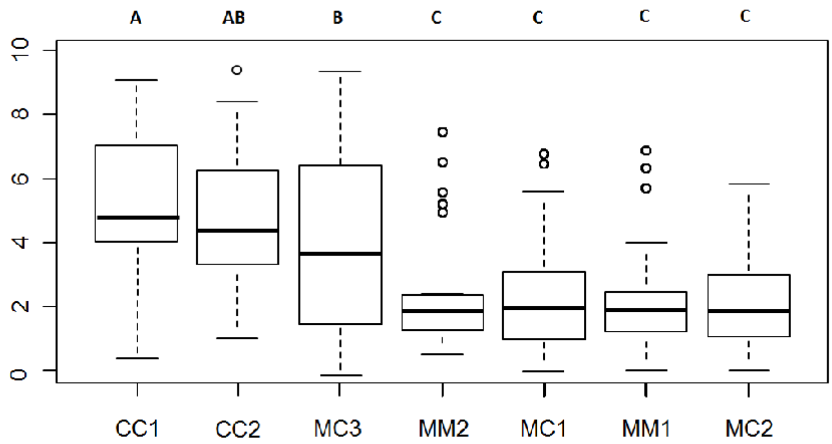
Vanilla mousse on chocolate cream (M-C):
Dessert A Sujet 10
Dessert A Sujet 02
Dessert A Sujet 03
Dessert A Sujet 04
Dessert A Sujet 07
Dessert A Sujet 08
Dessert A Sujet 09
Dessert A Sujet 17
Dessert A Sujet 18
Dessert A Sujet 20
Dessert A Sujet 21
Dessert A Sujet 22
Dessert A Sujet 26
Dessert A Sujet 27
Dessert A Sujet 30
Vanilla mousse on chocolate mousse (M-M):
Dessert B Sujet 01
Dessert B Sujet 05
Dessert B Sujet 06
Dessert B Sujet 19
Dessert B Sujet 24
Chocolate Cream on caramel cream (C-C):
Dessert C Sujet 11
Dessert C Sujet 16
Dessert D Sujet 12
Dessert D Sujet 13
Dessert D Sujet 15
Dessert E Sujet 14
Dessert C Sujet 32
Dessert D Sujet 23
Dessert D Sujet 29
Dessert E Sujet 25
Dessert E Sujet 28
Dessert E Sujet 31
Full cup (100%)
Empty cup (0%)
(A)
(B)
Spoon with only vanilla mousse
Spoon with only chocolate cream/mouse
Spoon with only caramel
Spoon with different layers
Spoon with the mix of different layers

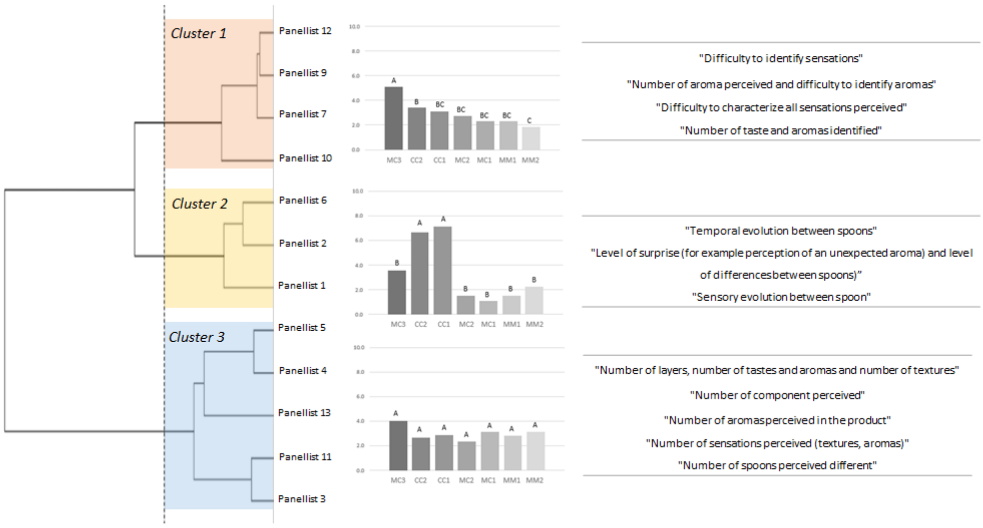
2xMM
3xMC
CC1
CC2
Dim2 (33.42%)
Dim1 (60.82%)
3
1
0
-1
-6
-4
-2
0
2

CARAMEL
SWEET
MILK
VANILLA
CHOCOLATE
Dim 2 (33.42%)
Dim 1 (60.82%)
1.0
0.5
0.0
-0.5
-1.0
-2
-1
0
1
2



A
AB
B
C
C
C
C
CC1
CC2
MC3
MM2
MC1
MM1
MC2

Cluster 1
Cluster 2
Cluster 3
Panellist 12
Panellist 9
Panellist 7
Panellist 10
Panellist 6
Panellist 2
Panellist 1
Panellist 5
Panellist 4
Panellist 13
Panellist 11
Panellist 3
"Difficulty to identify sensations"
"Number of aroma perceived and difficulty to identify aromas"
"Difficulty to characterize all sensations perceived"
"Number of taste and aromas identified"
"Temporal evolution between spoons"
"Level of surprise (for example perception of an unexpected aroma) and level of differences between spoons)"
"Sensory evolution between spoon"
"Number of layers, number of tastes and aromas and number of textures"
"Number of component perceived"
"Number of aromas perceived in the product"
"Number of sensations perceived (textures, aromas)"
"Number of spoons perceived different"

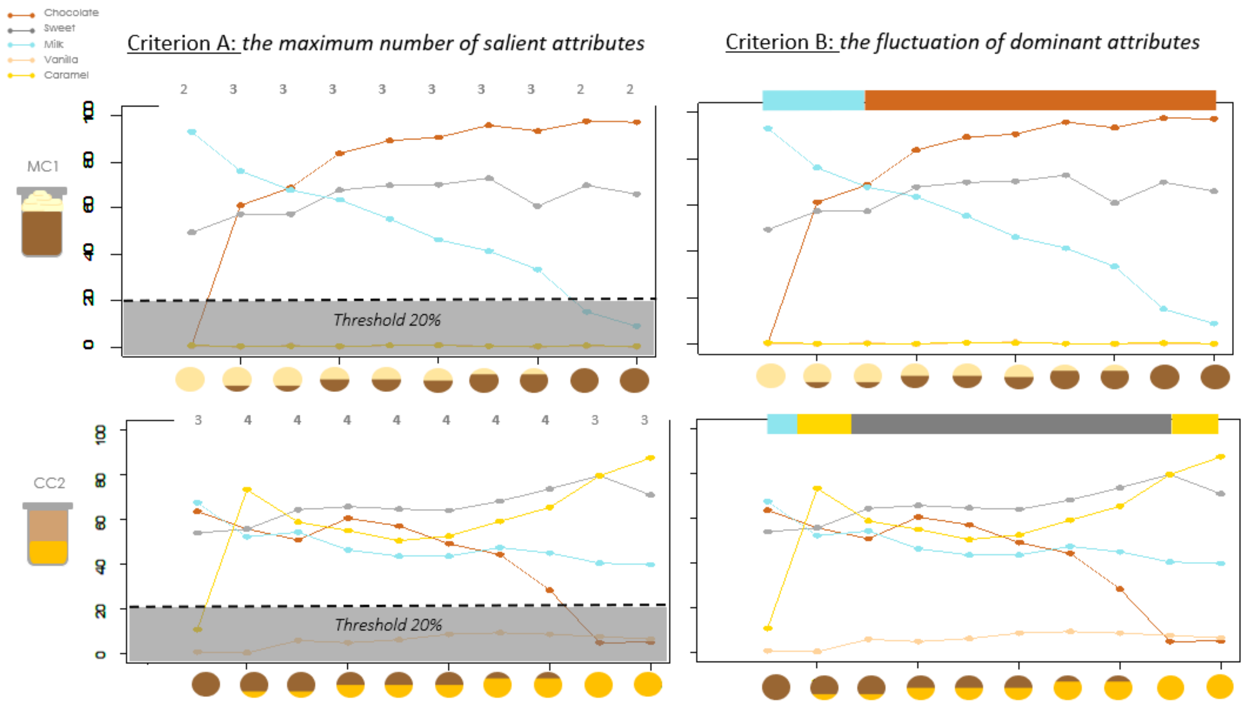



Table 1. Detail of the 8 desserts used in Experiment 2

| | Top Layer (proportion) | Bottom Layer (proportion) | Cup size (g) |
|---|---|---|---|
| Dessert MC1 | Vanilla Mousse** (1/3) | Chocolate Cream* (2/3) | 100 |
| Dessert MC2 | Vanilla Mousse (1/3) | Chocolate Cream (2/3) | 100 |
| Dessert MC3 | Vanilla Mousse (1/3) | Chocolate Cream (2/3) | 130 |
| Dessert MM1 | Vanilla Mousse** (1/2) | Chocolate Mousse (1/2) | 80 |
| Dessert MM2 | Vanilla Mousse (1/2) | Chocolate Mousse (1/2) | 80 |
| Dessert CC1 | Chocolate Cream (1/2) | Caramel Cream (1/2) | 85 |
| Dessert CC2 | Chocolate Cream* (2/3) | Caramel Cream (1/3) | 125 |

*desserts with the same chocolate cream, **desserts with the same vanilla mousse

Vanilla mousse = whipped cream analogue

Table 2. List of sensory attributes and their definitions

| Attribute | Definition, Protocol | Scale anchors | Anchors |
|---|---|---|---|
| Sweet | Basic taste, perceived on the tongue, stimulated by sugars | Not / Very | |
| Milk flavor | Retronasal aroma perception to condensed milk (evaluated after swallowing) | Not/Very intense | Condensed milk |
| Chocolate flavor | Retronasal aroma perception to baking chocolate (evaluated after swallowing) | Not/Very intense | Dark cooking chocolate |

| | | |
|---|---|---|
| Vanilla flavor | Retronasal aroma perception to vanilla extract (evaluated after swallowing) | Not/Very intense |
| Caramel flavor | Retronasal aroma perception to liquid caramel (evaluated after swallowing) | Not/Very intense |

Table 3. Results of the 3-way ANOVA for all descriptors

| | | Chocolate | | Caramel | | Milk | | Sweet | | Vanilla | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | DoF | F | p | F | p | F | p | F | p | F | p |
| Panellist | 11 | 45.7 | <0.0001 | 20.8 | <0.0001 | 37.7 | <0.0001 | 71.5 | <0.0001 | 19 | <0.0001 |
| ProductSpoon | 69 | 81.6 | <0.0001 | 420.4 | <0.0001 | 42.6 | <0.0001 | 32.7 | <0.0001 | 9.5 | <0.0001 |
| Rep | 1 | 3.7 | 0.10 | 2.4 | 0.12 | 10.1 | 0.07 | 27.4 | 0.08 | 21.9 | <0.0001 |
| Panellist*ProductSpoon | 759 | 2.4 | <0.0001 | 3.7 | <0.0001 | 2.2 | <0.0001 | 2.6 | <0.0001 | 1.9 | <0.0001 |
| Rep* ProductSpoon | 69 | 0.7 | 0.96 | 1.0 | 0.47 | 0.9 | 0.61 | 1.0 | 0.50 | 1.8 | 0.0002 |
| Panellist* Rep | 11 | 6.4 | 0.0001 | 7.4 | <0.0001 | 3.1 | 0.0003 | 7.7 | <0.0001 | 9.9 | <0.0001 |

Table 4. Pearson correlation coefficients per panellist between scores of perceived complexity and scores for criterion A and criterion B (significant correlations at the 10% threshold appear in bold).

| | | **Criterion A** | **Criterion B** |
|---|---|---|---|
| **Cluster 1** | Panellist 7 | **0.87** | **0.78** |
| | Panellist 9 | **0.69** | **0.58** |
| | Panellist 10 | **0.67** | **0.89** |
| | Panellist 12 | **0.78** | **0.64** |
| **Cluster 2** | Panellist 1 | **0.59** | **0.77** |
| | Panellist 2 | **0.66** | **0.78** |
| | Panellist 6 | **0.71** | **0.89** |
| **Cluster 3** | Panellist 3 | **0.57** | **0.68** |
| | Panellist 4 | 0.21 | 0.25 |
| | Panellist 5 | 0.11 | 0.16 |
| | Panellist 11 | **0.79** | **0.72** |
| | Panellist 13 | **0.80** | 0.09 |