Highlights:

- Virtual reality used as technology in sensory science.
- Opportunities generated by Virtual Reality for multidisciplinary collaboration
- Effect of both virtual and real contexts in pastries' visual expectations by consumers
- Comparison of visual evaluation of live pastries with their virtual versions.

IMPACT OF CONTEXT IN VISUAL EVALUATION OF DESIGN PASTRY: COMPARISON OF REAL AND VIRTUAL

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Abstract

Virtual reality is becoming an opportunity for multidisciplinary collaboration, including sensory science. The main objective of this work was to compare visual expectations generated by five real cakes evaluated in a laboratory testing booth with their virtual versions in a virtualized sensory booth. Real cakes were designed following the current pastries trends, and virtualization was made using a photogrammetric process. The virtual sensory booth was designed using Unity3D software. The participants were immersed in the 3D virtual environment through a head-mounted display (HMD). Data were analyzed using ANOVA mixed model, internal preference mapping and cluster analysis. The effects of context (real and virtual), the order in test session (crossover design), and socio-demographic factors were studied. The results showed no statistically significant differences within real and virtual studied cakes. These results create new perspectives of the potential of this methodology to be used to rate virtual foods in an immersive environment at the same level as real foods. Regarding the impact of the socio-demographic factors on the acceptance of the cakes, only the effects of gender and sweet-tooth were statistically significant. Males assessed all variables associated with the cakes significantly higher ($p<0.05$) than females. In the same way, all variables in all cakes were better evaluated by participants with a self-declared sweet-tooth ($p<0.05$). In the internal preference map, participants were segmented into three clusters that could be identified with the different trends in the pastries market. These results may help companies build tailor-made marketing strategies using Immersive technologies to evaluate new food products to satisfy different consumer segments.

Key words: virtual reality; virtual food; virtual context; cakes; gender effect; internal preference map.

1. Introduction

In the last decades, the most creative chefs around the world have been using scientific knowledge to innovate in their restaurants, therefore enhancing demands for innovation in complementary gastronomy areas such as bakery, pastries, food delivery, and beverages (Albors-Garrigos et al., 2013; Martínez-Monzó et al., 2013). Traditional pastry based on empirical and intuitive experience has progressively transformed into a creative profession with rigorous knowledge of food ingredients and strong technical skills. This high-quality Fine Pastry, while demanding in technique, has a whole aesthetic and emotional sensitivity in an amalgam of flavours, colours, textures and shapes of different ingredients (Rodes & Hernandez, 2011).

Fine Pastry is one of the most popular and increasing food categories to innovate in, due to its global consumption and sales as well as product range. Changes or modifications to the composition of these new creations can have an impact on the organoleptic characteristics of the final product, however, it is essential to ensure that consumer acceptance is maintained (Birch & Bonwick, 2019).

Market studies introduce the following key bakery and pastry trends for the next years: “Indulgence”, “Fusion”, “Identity”, and “Eatertaiment” (Fona International, 2019). “Indulgence” refers to guilt-free enjoyment, where chocolate remains the most desired ingredient, and with over 80% of consumers considering that a balanced diet can include some indulgence. “Eatertainment” searches for new and different experiences, with new and exciting ingredients, sophisticated designs, and attractive appearances to be shared on social media. “Fusion” places its emphasis on global-inspired flavours, inspired in sweet-and-salty caramel sauces with unexpected creative textures. And finally, the “Tradition” trend, which aims to vindicate the identity and culture in each region (Fona International, 2019).

In the marketplace, people do not have the ability to taste food prior to purchase. Therefore, the consumer creates a series of expectations based on both intrinsic and extrinsic product cues. Intrinsic cues are associated to the product’s sensory aspects (appearance, size or visual structure, texture, or flavour) and are one of the major food choice determinants (Cunha et al., 2018). On the other hand, extrinsic characteristics such as logo, packaging, brand, claims or even retail context, contribute to generate these expectations (Kpossa & Lick, 2020), where the evaluation of this plethora of cues by the consumers combines physiological, emotional and cognitive responses, which play a fundamental, often unconscious, role in consumer decisions (van der Laan et al., 2011).

Since 2014, multisensory experiences (including visual, olfactive, auditive and tactile stimuli) have been designed to provide gastronomic dining experiences (Crofton et al., 2019; Youssef & Spence, 2021). The arrival of Covid-19 has accelerated many of the trends that were already in place before the pandemic, especially those that allowed the reduction or elimination of contact between people. The scenario has changed completely, and the virtual is replacing the physical everywhere: medical centres, hospitals, offices and small businesses, meeting places and entertainment, among others, as well as in teaching and science (Barnes, 2020). In this digital context, virtual reality offers emerging opportunities for the discipline of sensory science (see review Crofton, 2019). In his review, Crofton shows that virtual reality can be applied in the form of context-enhancing technologies by replacing real environments with immersive settings, improving the ecological validity of research, and allowing for a better prediction of consumer sensory evaluations. This can be an opportunity to promote safety and create memorable experiences, in turn helping the gastronomy sector to redefine its future (Garibaldi & Pozzi, 2020; Schiopu et al., 2021). In this frame, there are two key points that must be considered when translating from the real to the virtual world, or vice-versa: the characteristics of the product itself (Köster, 2009) and the traits of the specific context in which the tasting takes place (Bangcuyo et al., 2015; Dacremont & Sester, 2019; Jaeger & Porcherot, 2017; Kim et al., 2015; King et al., 2007) -the latter being the more increasingly explored.

A consumer test in the absence of a context may imply a "situational fallacy", leading to less involvement and consequently to an irregular and invalid hedonic classification (Köster, 2003). The same food product served in a different context (sensory booths, restaurant, home, etc) is perceived with different hedonic quality (Boutrolle et al., 2007; García-Segovia et al., 2015; King et al., 2007). Virtual Reality (VR) is becoming a great opportunity for multidisciplinary collaboration. The use of VR is emerging as an alternative to physically created immersion environments. With this technology, consumers wear VR helmets/glasses to experience a complete visual and audio environment (Porcherot et al., 2018; Siegrist et al., 2019). There are increasing possibilities to simulate real situations on a computer and promote users' immersion and sensations in different environments (Bangcuyo et al., 2015; Kong et al., 2020; Netto & Oliveira, 2004; Picket & Dando, 2019; Schnack et al., 2019; van Bergen et al., 2021; Wang et al., 2020). Virtual environments are designed to provoke high user involvement and provide extrinsic contextual information, presenting enormous potential as an ideal alternative to traditional environments used in sensory analysis (Hathaway & Simons, 2017). Recreation of usual food consumption scenarios through immersive methodologies, such as VR, has been increasingly used by different researchers. Sinesio et al. (2019) compared the acceptance and emotional responses in consumption of different types of beers, in a virtual pub, a real pub, and a traditional central location test. Torrico et al. (2020) evaluated and compared perception, sensory acceptability, and emotional responses of a Cabernet Sauvignon wine in traditional sensory booths, contextual environments, and VR simulations. Stelick et al. (2018) developed a study where consumers were invited to taste three identical samples of blue cheese in three different contexts, a sensory booth, a virtual garden bench, and a virtual cow stable.

The choice of a food product is a complex process that depends on different interrelated variables. Changes to food texture during eating have an intense influence on food choice and acceptance of new products (Crofton et al., 2019). However, consumer perceptions or choices could be very sensitive to the visual realism of the food image depicted (Crofton et al., 2019). Appearance provided by the sense of vision is a more effective means of foraging, predicting which foods are likely going to be safe and nutritious to consume, and generating those expectations that will constrain the consumption experience (Spence et al., 2016; Stierand, 2016). At the moment, only Gouton et al. (2021) has compared VR with a real environment. In this work authors used a set of chocolate cookies to validate visual attribute perception assessed in real conditions (real cookies in natural environment) and VR (virtual cookies presented in VR in the same context). All results suggest that this technology is promising to provide a frame for further applications, such as the possibility of personalized design food products based on consumer expectations, desires, or preferences, offering food companies, retailers, restaurants or small businesses a new opportunity to digitalize and innovate (Wang et al., 2021).

For both context and food product, it is essential to ensure a realistic quality of the visual simulation due to consumer perceptions, as choices are very sensitive to the visual realism depicted (Crofton et al., 2019; Gouton et al., 2021; Ledoux et al., 2013). Currently, one of the most representative virtualization software on the market is the 3DS MAX software, its interface being simple and clear, and having a powerful modelling function, widely applied in the creative design industry (Peng et al., 2011).

Based on the opportunity that VR offers to sensory science, the main objective of this work was to compare participants' visual expectations in real and virtual environments using the same context (testing booth) and the same five designed cakes. The impact of age, gender, eating behaviour, nutritional knowledge and socioeconomic variables on visual expectations was also studied as a secondary objective.

The overarching goals of this work are to evaluate if the mere immersion in a virtual environment would have any impact on the evaluation of food product expectations, and if a virtual sensory booth would allow relevant immersion, keeping the same discriminating power as a real life laboratory booth, thus opening new avenues for the set-up of sensory testing under COVID-19 or any other situation of restricted access to a sensory lab.

2. Material and methods

2.1 Participants recruiting

One hundred and ten participants were recruited from *Universitat Politècnica de València*'s participant database. The participants were recruited using a convenient intentional and reasoned sampling with predetermined inclusion criteria: a) at least occasional consumption of special cakes, b) self-reported intermediate interest in technology, c) free from allergies or diabetes disease. This non-probabilistic method is used more often than any other sampling in behavioural science to reach a first approach of results related to a research subject (Carrillo, 2012; Graveter & Forzano, 2008; Guerrero et al., 2010). In the recruitment phase, no information was provided about the objective of the project. The Institutional Review Board was informed, and this study was reviewed and approved. All subjects gave their informed consent before engagement in the study. For data security purposes, all subjects were assigned a random three-digit code. Data was treated anonymously and following the European General Data Protection Regulation (Regulation E. C., 2016).

2.2 Environment design: real versus virtual sensory booth

In the Real environment, the sensory booth of the Polytechnic Innovation City (at *Universitat Politècnica de Valencia*) was used (Figure 1a). The visual evaluations were carried out individually in sensory booths, without contextual tracks, under white lighting. The ambient temperature (22 ± 2 °C) and air circulation were controlled during the sessions (ISO, 2014).

In the Virtual environment, a duplicate sensory booth (Figure 1b) was created by taking photographs with a 360-degree panoramic view combined with 3D elements in the background, using the 3DMax software (Autodesk, Mill Valley, CA). This resulted in a realistic environment and faithful reproduction of the sensory booths used in the real context, designed using the Unity3D software (Unity Technology, Copenhagen, DK). The participants were immersed in the 3D virtual environment through a head-mounted display (HMD) Oculus Rift S (Lenovo, Hong Kong, China), in which the virtual environment was presented. This device allowed subjects to move and turn their heads in the virtual world in a very natural and realistic way (Figure 1c).

**Figure 1

2.3 Stimulus

In line with current trends, five cakes with different characteristics designed by "Casa La Curra" (Torrent, Valencia, Spain) were used in this study (Figure 2). Following the "Indulgence" trend, a "Coulan" (C) cake with molten chocolate heart of Guanaja 70% and raspberries (Figure 2a) was created. Considering the "Eatertainment" trend, the "Leonor cake" (LC) and "Saffron cake" (SC) were designed. LC was made of a *dacqouise* of coconut and almonds at the base, filled with a creamy almond praline and 34% Ivorie lemon mousse with white chocolate and decorated on the surface with pieces of candied orange (Figure 2b). SC consisted of a base of butter biscuit filled with a saffron cream with granny smith apple, steamed with saffron, rosemary honey and mousse of Manjari chocolate 64% (Figure 2c). "Walnut cake" (WC) represented the "Fusion" trend, being made of a *sablee breton* consisting of salted caramel cream, nuts, and creamy milk chocolate (Figure 2d). Finally, the "Chocomuffin" (CM) is a conventional muffin incorporated with a filling of 70% Guanaja chocolate (Figure 2e) representing the "Tradition" trend. The cakes were all frozen and taken out of the freezer 30 minutes prior to testing.

**Figure 2

All the pastries were also virtualized using a photogrammetric process (Figure 2a-e). In this study, 3DS Max was used to create a premium realistic context. To obtain the most realistic render of our fine cakes, the real products were virtualized using a photogrammetric and 3D scanning process. The photogrammetric process consisted in collecting 80 pictures of the cakes in a hemispherical space by mean of the Orbitvu ALPHASHOT XL V2 3D scanner (Orbitvu, London, UK). These photographs were later used to obtain an accurate and highly photorealistic 3D model of each cake, using the RealityCapture software (Capturing Reality, Bratislava, SK) and the reconstructions were exported to .fbx format supported by Unity 2017.2.0f3® software.

The samples were presented in a randomized order between participants, while remaining the same across testing environments for each participant, to avoid changes in hedonic scores due to order effects (Mead & Gay, 1995) and to help ensure that the main variable influencing the data was the environmental difference.

2.4. Design and procedure

A crossover experimental design was selected. In this experimental design, participants were divided into two groups and different contexts (Real and Virtual) were evaluated during two time periods. After three weeks, the participants crossed over from one context to another. Between time periods, a washout time was aimed to minimize the probability of participants memorizing the answers (carry over effect). This design yielded a more efficient context comparison, as fewer participants were required to attain the same level of statistical power or precision as other statistical designs. Each group was balanced with respect to their age group (χ_2^2 =3.727, p = 0.155) and gender (χ_1^2 =3.456, p = 0.063).

The experimental procedure was properly explained to all participants before the test started and each session lasted approximately 15 minutes. The sessions took place between 10:30h and 12:00h in the morning and between 18:00h and 19:30h in the afternoon. Initially, participants rated their appetite by evaluating hunger on a 7-point Likert scale, in which the anchors ranged from 1 ("Not hungry") to 7 ("Very hungry"). The five cakes were presented monadically in a blind condition (labelled with random three-digit codes) following a complete balanced design. The virtual context was visualized by means of a head mounted display (HMD), model Oculus Rift S (Oculus Rifts S, Lenovo). The participants used a 7-point anchored scale to evaluate visual expectations about appearance (1-Extremely unacceptable to 7-Extremely acceptable), serving size (1-Extremely inadequate to 7- Extremely adequate), deliciousness (1-Extremely unpleasant to 7-Extremely delicious), and liking (1-Extremely dislike to 7- Extremely like) under both Real and Virtual environments. All participants answered the same questionnaire, which only varied in the way it was carried out between the different environments. For the Virtual context, a 3D digital questionnaire was developed, and the interaction of the user with the 3D questionnaire was done by means of a natural user interface using the 3D controllers of the HMD (Oculus Rifts S, Lenovo). In the real context, the panel responses were recorded on a tablet (10.1" Lenovo Tab E10, Hong Kong, China). Both experiences did not involve any tasting of the cakes.

2.5. Questionnaires

After evaluation, participants were asked to complete a structured electronic questionnaire. The questionnaire consisted of several sections dealing with (1) behavioural and eating habits, based on two previous studies by Márquez-Sandoval et al. (2014) and Unikel-Santoncini et al. (2004); (2) nutritional knowledge, based on the study by Parmenter & Wardle (1999); and (3) when the test was carried out in a Virtual context, as a measure of the sense of presence in the virtual environment, participants responded to a sense-of-presence questionnaire, based on Slater et al. (1994). Personal data relating to lifestyle, general interests and socio-demographics were also registered.

2.6. Statistical Analysis

To analyse the collected personal lifestyle, general interest and socio-demographics data, basic descriptive statistics and variable characterization was carried out.

Differences in the visual evaluation of the cakes, relative to the cross-over design were assessed using linear mixed model analysis of variance (ANOVA) with participants as a random effect, and order of test session (First vs Second) and type of cake as fixed factors, where cakes were nested to both the Virtual and Real contexts. Other variables related to the personal profile of participants such as age, gender, subjective hunger, sweet tooth preference, eating habits, nutritional knowledge, and presence in the virtual context were also analysed using a nested ANOVA model. A Fischer LSD post hoc test was also applied to estimate the differences between groups.

An internal preference map was prepared in order to study the relations between the participants' responses and their expected liking for the samples. The map was carried out using principal component analysis (PCA) of the correlation matrix of variables for each cake (objects), followed by a hierarchical cluster analysis (HCA), using Euclidean distances and Ward's method, to identify groups of participants with different expected liking. After obtaining the clusters, the individual participants were identified and represented with different symbols on the previously plotted preference map. To confirm that they differed from each other, a one-way ANOVA was applied on the mean of the expected evaluations. To better understand which aspects characterize the different clusters, a one-way ANOVA analysis was applied to compare cluster means and the variables related to participants' visual expectations. Moreover, chi-square tests were used to verify significant differences between clusters in socio-economic and demographic data.

Quantitative data were reported as means and standard deviation, and the Fischer (LSD) multiple comparison test was applied to inspect for significant differences in the visual evaluation of cakes, with a 95% confidence level. Significant differences in qualitative data were analysed according to the Chi-square in k proportions test. All data analyses were performed using the XLSTAT statistical software v. 2021.2.1 (Addinsoft, 2020).

3. Results

3.1. Influence of crossover design effects and participants' profile factors affecting visual evaluation of cakes.

Differences in participants' visual expectations of the appearance, size, deliciousness, and liking of the five cakes under the two conditions (Real and Virtual context) and the order of the test session (first or second) were analyzed with ANOVA mixed models. Results are presented in Table 1. Only the factors cake (fixed) and participant (random) provide significant information to explain the variability in the visual evaluation of the measured variables.

**Table 1

When comparing the data between cakes (Figure 3.1) a similar pattern is shown for the Real and Virtual contexts. The Leonor cake (LC) was evaluated significantly higher ($p<0.05$) than other cakes in the Virtual environment, for appearance, deliciousness, and expected liking. In both contexts, appearance for Chocomuffin (CM) and Saffron cake (SC) was ranked significantly less than others. A similar pattern was observed for SC regarding serving size.

Across the experimental contexts, concerning the visual evaluation, no statistically significant differences were observed within cakes (Figure 3.2), except deliciousness for Coulan cake (CC) (discussed below). Therefore, for each type of cake, the Virtual environment neither worsened nor improved assessments when compared to the Real context, indicating the potential of this methodology to be used to rate virtual foods in an immersive environment at the same level as real foods.

**Figure 3

Results from the ANOVA model with the socio-demographic participant profile, indicated that only gender, self-declared sweet tooth, and type of cake were significant ($p<0.05$) in the visual evaluation of real and virtual cakes, while the serving size was not ($p = 0.238$). No significant interactions between these factors were detected (Table 2). Other factors in the model such as age, level of hunger, eating habits, nutritional knowledge, or presence in Virtual context (previously clustered) did not bring significant information to explain the variability in visual expectations. Fischer's post hoc analyses identified differences between groups, also presented in Table 2. Males assessed all variables significantly higher ($p<0.05$) than females. In the same way, significant differences ($p<0.05$) were found in participants that self-declared as having a sweet tooth. Among the other factors, type of cake had the most influential effect. No significant differences were found within-cake in the two contexts, except for deliciousness of the CC (Table 2, Figure 3.2), probably due to the color and brightness of the Virtual CC being different from the expected (Spence & Piqueras-Fiszman, 2016). On the other hand, significant differences ($p<0.05$) were observed between cakes for all visual expectations. In all visual parameters evaluated, SC was the worst ranked and LC obtained higher evaluation rates.

**Table 2

3.2. Participants' expected liking

The results obtained from the internal preference map, based on the expected liking scores of each of the 10 cakes (from virtual and real), yielded four dimensions explaining 66.1% of the variability. The squared cosines associated with the PCA are presented in Table 3, indicating which cakes are significantly correlated with each PC. Cakes considered to follow the "Eaterteinment" and "Fusion" trends (LC, SC and WC) were well linked with PC1 (squared cosines varied from 0.57 to 0.36). The CM, considered in the "Tradition" trend, was aligned with the vertical axis, which was PC2 (squared cosine was 0.65 and 0.38). The CC was associated with PC3 (squares cosines 0.49 and 0.32) separating the "Indulgence" trend from the others.

**Table 3

The internal preference map for participants with three clusters was obtained after HCA on the PCs with eigenvalues >1, and confidence ellipses were presented in Figure 4. In the biplot PC1 vs. PC2 (Figure 4), expected liking vectors of LC, SC and WC (real and virtual), were closely related to each other, indicating their positive association. In addition, CM was not associated with these trends of cakes as it was almost orthogonal, and it was negatively correlated with CC. No differences were observed within cakes across the contexts.

Observing participants' segmentation after HCA, Cluster 1 (C1, n=39), placed mainly on the bottom-center of the map (Figure 5a), showed better liking expectation for the CC, and lower for CM. Participants in C1 could be aligned with "Indulgence" values. Participants in Cluster 2 (C2, n=38) had higher liking expectations for more "Eatertainement" cakes. Finally, Cluster 3 (C3, n=27) indicated a more traditional group, with higher expected liking for CM as the "Tradition" value.

**Figure 4.

A one-way ANOVA showed that the three clusters differed significantly ($p < 0.0001$) from each other with respect to the means of all visual expectations evaluated (Table 4). Three clusters presented the same approach in all visual evaluations following the expected liking used to determine HCA after PCA.

Cluster 2, with 36.5% of the total 104 participants, mainly linked with the "Eatertainement" trend, included those who scored the highest in all visual evaluations, as opposed to Cluster 3 (25.9%), most identified with the "Tradition" trend, which scored the lowest.

**Table 4

From the socio-demographics data analysis, all three clusters presented similar characteristics (Table 5). No significant differences were detected between them for age, body mass index (BMI), nationality, educational level, monthly income, or partnership life. Differences were observed in gender and self-declared sweet tooth. Cluster 3, which was identified in the PCA as having a greater link with the "Tradition" trend, had a significantly higher percentage of females and had less of a sweet tooth. Cluster 2, related to the profile "Eatertaimnement", was characterized by a significantly higher percentage of males, and self-declared sweet tooth . No significant overall differences in monthly income were shown between clusters, except for participants who declared high incomes, where differences between Cluster 2 and Cluster 3 were found to be significant.

**Table 5

4. Discussion

In the last five years, immersive VR environment experiences have been used to study the effect of the consumption context on participant sensory testing involving food choice (Cheah et al., 2020; Fang et al., 2021; Goedegebure et al., 2020; Isgin-Atici et al., 2020; Lombart et al., 2020; Xu et al., 2021) or food evaluation (Ammann et al., 2020; Barbosa Escobar et al., 2021; Chen et al., 2020; Kong et al., 2020; Korsgaard et al., 2019; Nivedhan et al., 2020; Stelick et al., 2018; Torrico et al., 2020; Torrico et al., 2021; Wang et al., 2020; Worch et al., 2020). This work was framed in the application of VR technologies, where the participant was immersed in the full virtual environment, hence what is experienced exists only in the virtual world. The same environment and product were evaluated in a real sensory evaluation booth. To our knowledge, similar work was implemented by Gouton et al., (2021). In their work, authors compared participants' visual descriptions of real commercial cookies with their virtualized versions. In this case, authors concluded that descriptors elicited in visual tests were similar for both real and virtual experimental conditions. Despite differences in studied participant responses, our results are in accordance with these authors: no significant differences between cakes (real or virtual) were found in visual expectations, except for the deliciousness evaluation for the Coulan cake. Shape and colour (dark chocolate) was a limitation to obtain a photorealistic texture after virtualization (see figure 2a). This result was in agreement with results obtained by Zhang & Seo (2015) which observed in an eye-tracking study that colour and brightness in food pictures influenced participants' visual attention. In the same way, Zellner et al., (2010, 2014) reflected upon how manipulating colour and balance in food presentation affected its attractiveness. There are very few studies that focused on comparing VR and pictures, and there are even fewer that compared food recreated through virtual reality and food recreated through pictures. Nevertheless, it is know that the behavior of consumers is more identical to real life when presented with virtual cues as opposed to pictures (van Herpen et al., 2016). Additionally, it has been shown that virtual food is as effective as real food, and more effective than photographs of food, in producing psychological and physiological responses in patients with eating disorder, suggesting a possible advantage of using virtual stimuli instead of static pictures as an alternative to real stimuli to induce emotional reactions in subjects. Virtual food cues elicited similar anxiety levels in participants as those elicited by real food cues, and higher anxiety than those elicited by picture cues (Gorini et al., 2010).

In both experiences (Virtual and Real), only differences between pastries were observed. Visual perception, mainly colour, influences food expectations in different ways (Spence, 2015, 2018; Wadhwani & McMahon, 2012), playing an important role in expected liking. The five cakes (real and virtual) presented to participants in this experience had different visual structures with the colour, gloss, translucency, and surface texture characteristic of its ingredients, following trends in the pastry market. As mentioned in some research~~es~~, visual attributes impact visual attractiveness and contribute to the identification of different ingredients, generating taste and flavour expectations and the quality of pastries (Paakki et al., 2019a; Paakki et al., 2019b), which can justify the differences found. In the crossover experimental design, participants were divided in two groups, one group started with the Virtual context and the second group started with the real one. Each one took part in two sessions and no differences were observed between the first and second session. The results were in line with the ones presented by Gouton et al. (2021).

Gender differences, especially gender stereotypes, have been studied in food (Cavazza et al., 2015, 2017; Kimura et al., 2009, 2012; Vartanian et al., 2007), but also in the field of diet and social media (Nelson & Fleming, 2019), online cooking prejudices (Rokicki et al., 2016), and food choices and behaviours (Fagerli & Wandel, 1999; Grogan et al., 1997; Roos et al., 1998; Wardle et al., 2004). Most of these studies noted that despite women having healthier food habits, they paradoxically show higher levels of restrictive and emotional eating behaviours than men (Basow & Kobrynowicz, 1993; Conner et al., 2004; Grogan et al., 1997). These differences can be explained not only by differences in diet but also by cognition and motivation (Wardle et al., 2004) derived from different social norms, social media pressure to have the perfect body (Pritchard & Cramblitt, 2014), and learning about masculine or feminine eating styles (Cavazza et al., 2020; Chaiken & Pliner, 1987; Graziani et al., 2021; Rolls et al., 1991). Nutritional value as a signal of healthy food is also associated to gender roles. In this way food that is high in calories and fat is related with men, while food low in calories and fat is with women (Barker et al., 1999). In line with these studies, our results suggest that the visual evaluation of cakes is conditioned by gender stereotypes, and support the idea that the gender-based stereotypes about food are more binding for women than for men (Cavazza et al., 2020). Similar results were also presented in several studies about gender differences in eating sweet snacks (Grogan et al., 1997), sandwiches (García-Segovia et al., 2021), insect-based food alternatives (Caparros et al., 2016) or meat (Rozin et al., 2012). Cavazza et al. (2015) found that food type, portion size, and dish presentation influence the perceived association between food and gender.

The portion size effect has been studied by different authors (Sheen et al., 2018) (Robinson et al., 2015, 2016; Sheen et al., 2018) to relate the increase in portion size in the last decades with the increase of energy intake. In three experiences designed by Robinson et al. (2016) to study the effect that visual exposure to larger versus smaller food portion sizes had on participant perception of a normal portion size, authors did not find evidence that visual exposure to larger portions altered snack food intake. Contrarily, studies on nudging have shown that the portion size of chocolate cake and apple slices may have a clear impact on the amount eaten (Hansen et al., 2016). In our experience, each cake presented to participants in real or virtual environment had the same portion size. No differences were found within cakes. Between the cakes, the most traditional one (Chocomuffin) was evaluated as the most adequate in size. According to our results, one potential interpretation can be that familiarity affects the importance attributed to the portion size in traditional cakes (virtual and real). In this sense, an interesting work about the effect of portion size using virtualized food/environment will be important for future research.

5. Limitations

These results should be observed with caution because of some limitations of this study. First, the study used mainly Spanish participants, with a moderate or high level of education, between the Z-generation and centennials by age, with a healthy weight, and not being usual users of immersive technologies. In order to generalize this outcome, a larger and more diverse population should be included in the following steps. Despite no significant differences being observed by participants for the same cake in each environment (Real or Virtual), some participants indicated differences in color and brightness between the virtual representation and the real Coulan cake. Considering that these effects might influence participants' visual attention (Frey et al., 2008), virtualizing processes for dark and brilliant foods should be improved. On the other hand, in this work, only visual expectations about appearance, serving size, deliciousness, and liking were evaluated. To evaluate the complete experience for participants, VR technologies must continue to evolve. The research team is studying ways to incorporate the use of multisensory stimuli, such as olfactory, auditive and tasting into further research.

6. Conclusions

This study found that real or virtual environments did not exert a significant influence on participants' expectations on visual appearance, serving size, deliciousness or expected liking for Fine Pastry. This result provides insight to design future experiences to compare how virtual environments (e.g., congruent or incongruent food contexts) could affect visual expectations or willingness to buy. Immersive technologies could be a viable alternative for companies to evaluate new food products flexibly and with cost effectiveness. Moreover, it demostrates a reinforcement of the opportunity to use virtual labs to evaluate perceived expectation towards food products, when consumers are kept away from the sensory lab, due to COVID-19 or any other circumstance.

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Figure 1

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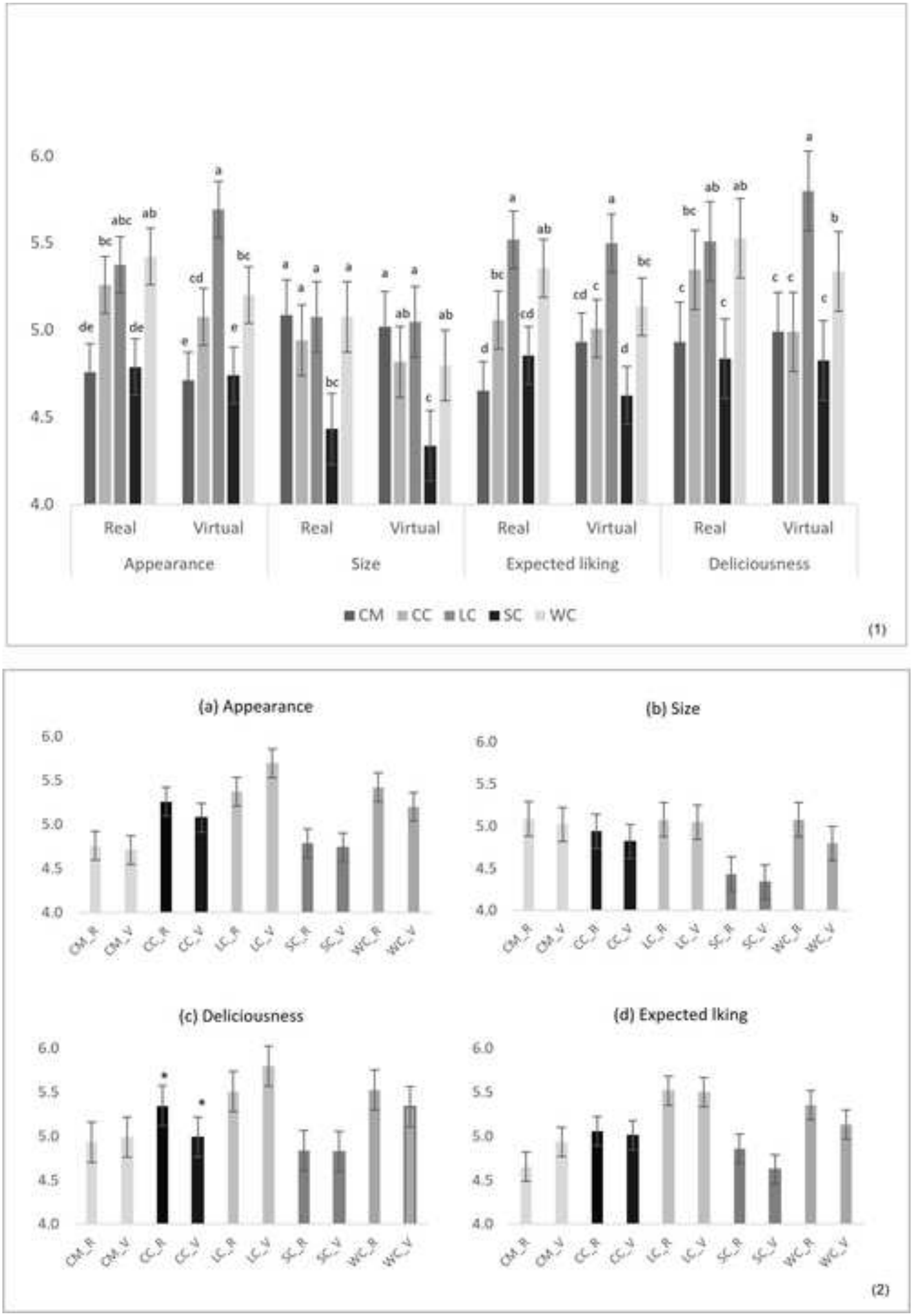
Figure 2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Appearance
Size
Expected liking
Deliciousness
CM
CC
LC
SC
WC
(1)
(a) Appearance
(b) Size
(c) Deliciousness
(d) Expected lking
CM_R
CM_V
CC_R
CC_V
LC_R
LC_V
SC_R
SC_V
WC_R
WC_V
(2)

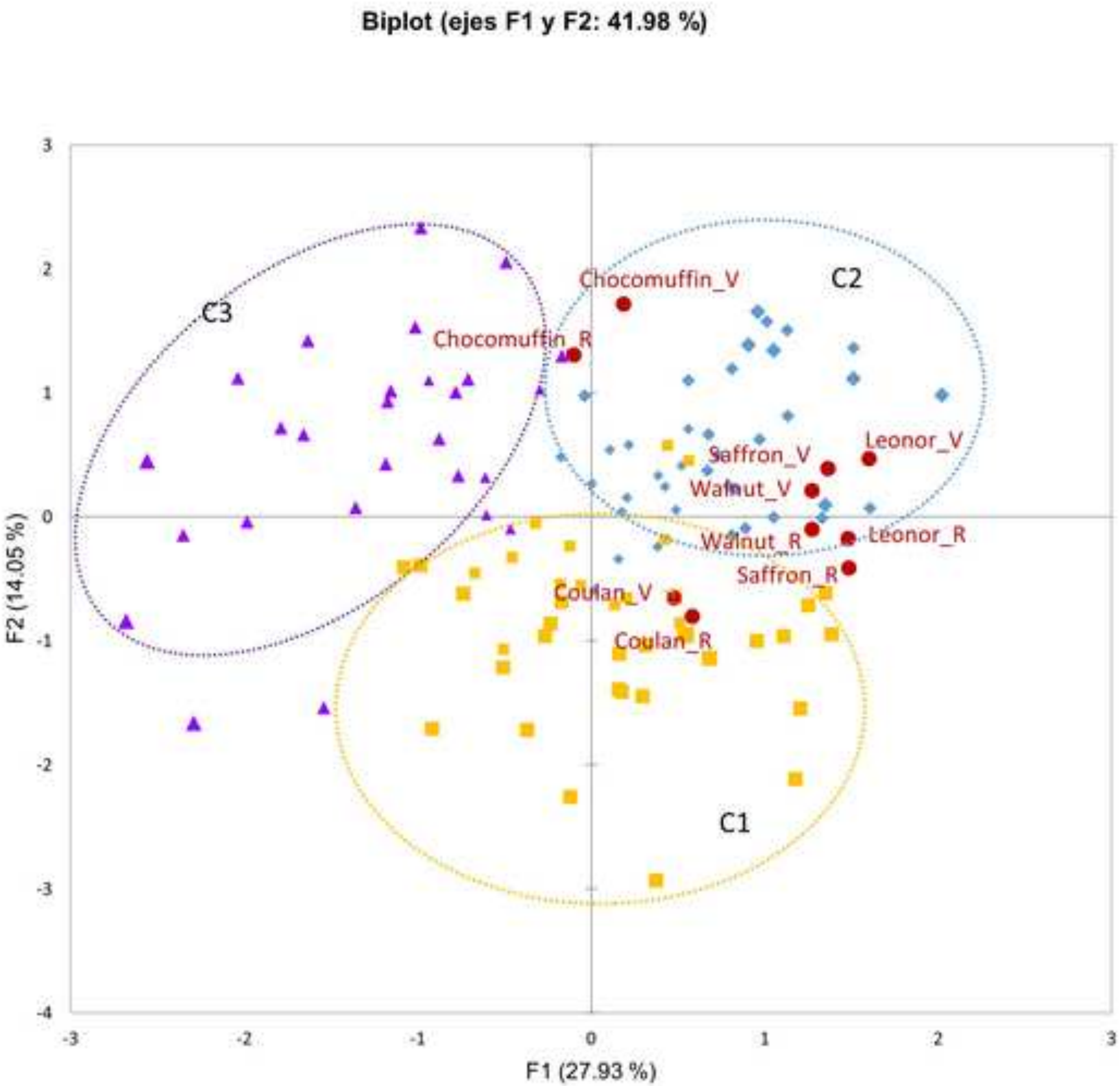
Biplot (ejes F1 y F2: 41.98 %)
C3
C2
C1
Chocomuffin_V
Chocomuffin_R
Leonor_V
Saffron_V
Walnut_V
Walnut_R
Leonor_R
Saffron_R
Coulan_V
Coulan_R
F2 (14.05 %)
F1 (27.93 %)
3
2
1
0
-1
-2
-3
-4
-3
-2
-1
0
1
2
3

Figure Captions

Figure 1. a) Real sensory Booth (at UPV), b) Virtual sensory booth, c) Participant with HDM ready to be immerse in the evaluation.

Figure 2. Real vs. Virtual stimulus designed by “Casa La Curra”: (a) Coulan cake (CC), (b) Leonor cake (LC), (c) Saffron cake (SC), (d) Walnut cake (WC), (e) Chocomuffin (CM).

Figure 3. Mean (LSD) of visual evaluation of five cakes under Real and Virtual conditions: (1) between cakes; (2) within cakes. Abbreviations: CC (Coulan cake), LC (Leonor cake), SC (Saffron cake), WC (Walnut cake), CM (Chocomuffin); R (real cake) and V (virtualized cake) (*) Only statistically significant differences are marked.

Figure 4. Internal preference mapping based on the visual expected liking ranking biplot PC1-PC2 Abbreviations: CC (Coulan cake), LC (Leonor cake), SC (Saffron cake), WC (Walnut cake), CM (Chocomuffin); R (real cake) and V (virtualized cake)

Table 1.- ANOVA mixed models to test significant differences of fixed and random effects from crossover design.

			Appearance		Serving Size		Deliciousness		Expected liking	
Source	**Type**	**DF**	**F**	**p-value**	**F**	**p-value**	**F**	**p-value**	**F**	**p-value**
Test session (TS)	Fixed	1	0.081	0.777	0.292	0.589	0.068	0.794	0.016	0.899
Context (V-R)	Fixed	1	0.225	0.635	1.587	0.208	0.314	0.575	0.395	0.530
Participant	Random	103	2.590	<0.0001	6.885	<0.0001	2.811	<0.0001	2.765	<0.0001
Cake	Fixed	4	17.410	<0.0001	7.259	<0.0001	16.726	<0.0001	14.320	<0.0001
TS*Cake	Fixed	4	0.657	0.622	0.169	0.954	0.790	0.532	0.273	0.896
Context*Cake	Fixed	4	1.627	0.165	0.220	0.927	2.168	0.071	1.481	0.206

Table 2.- ANOVA mixed models of socio-demographic consumer profile (only significance factors were added in the model)

Factor		Appearance Mean (DS)	Appearance p-value	Serving Size Mean (DS)	Serving Size p-value	Deliciousness Mean (DS)	Deliciousness p-value	Expected liking Mean (DS)	Expected liking p-value
Gender	Male	5.3(1.2)[a]	0.001	5.5(1.6)[a]	<0.0001	5.4(1.2)[a]	0.001	5.3(1.2)[a]	0.003
	Female	4.9(1.4)[b]		4.5(1.9)[b]		5.1(1.4)[b]		4.9(1.4)[b]	
Sweet tooth	Yes	5.2(1.3)[a]	<0.0001	4.9(1.8)[a]	0.015	5.3(1.3)[a]	0.002	5.1(1.3)[a]	0.001
	No	4.8(1.4)[b]		4.4(1.9)[b]		4.9(1.3)[b]		4.8(1.4)[b]	
Cake	Chocomuffin_R	4.8(1.3)[cd]	<0.0001	5.1(1.8)[a]	0.238	4.9(1.2)[d]	<0.0001	4.6(1.4)[d]	0.001
	Chocomuffin _V	4.7(1.3)[d]		5.0(1.8)[a]		4.9(1.3)[cd]		4.9(1.2)[cd]	
	Coulan cake_R	5.3(1.3)[b]		4.9(1.8)[a]		5.3(1.2)[b]		5.1(1.3)[bc]	
	Coulan cake _V	5.1(1.3)[bc]		4.8(1.9)[ab]		4.9(1.3)[cd]		5.0(1.3)b[c]	
	Leonor cake_R	5.4(1.2)[ab]		5.1(1.8)[a]		5.5(1.3)[ab]		5.5(1.2)[a]	
	Leonor cake _V	5.7(1.1)[a]		5.0(1.9)[a]		5.8(1.1)[a]		5.5(1.2)[a]	
	Saffon cake_R	4.8(1.4)[cd]		4.4(1.9)[b]		4.8(1.4)[d]		4.8(1.4)[cd]	
	Saffon cake_V	4.7(1.3)[cd]		4.3(1.9)[b]		4.8(1.4)[d]		4.6(1.3)[d]	
	Walnut cake_R	5.4(1.3)[ab]		5.1(1.9)[a]		5.5(1.3)[ab]		5.4(1.3)[ab]	
	Walnut cake_V	5.2(1.3)[b]		4.8(1.9)[ab]		5.3(1.3)[bc]		5.1(1.3)[bc]	

In each factor, similar letters denote homogeneous groups using post hoc Fischer LSD test ($p<0.05$).
Abbreviation: R (real cake); V (virtualized cake)

Table 3. Principal component analysis squared cosines table for cakes as active variable.

Active Variable	PC1	PC2	PC3	PC4
Chocomuffin_R	0.002	**0.378**	0.153	0.258
Chocomuffin_V	0.007	**0.653**	0.030	0.059
Coulan_R	0.074	0.142	**0.319**	0.166
Coulan_V	0.050	0.093	**0.485**	0.003
Leonor_R	**0.482**	0.006	0.056	0.006
Leonor_V	**0.566**	0.049	0.025	0.065
Saffron_R	**0.486**	0.037	0.109	0.073
Saffron_V	**0.411**	0.035	0.011	0.062
Walnut_R	**0.358**	0.002	0.041	0.148
Walnut_V	**0.356**	0.010	0.065	0.274

Note: Values in bold correspond for each variable to the PC for which the squared cosine is the largest.

Table 4. Clusters by visual expectations.

	All (N=104)	Cluster1 (N=39)	Cluster2 (N=38)	Cluster3 (N=27)	p-value
		Indulgence	Eaterainement	Tradition	
Appeareance*	5.1 (1.3)	5.0 (1.3)[b]	5.5 (1.1)[a]	4.3 (1.4)[c]	<0.0001
Serving size*	4.9 (1.9)	4.7 (1.8)[b]	5.6 (1.6)[a]	3.7 (1.9)[c]	<0.0001
Deliciousness*	5.2 (1.3)	5.1 (1.3)[b]	5.7 (1.1)[a]	4.4 (1.4)[c]	<0.0001
Expected liking*	5.1 (1.4)	4.9 (1.4)[b]	5.7 (0.9)[a]	4.1 (1.3)[c]	<0.0001

*Mean (SD). Different lower cases in the same line means a significant difference ($P < 0.05$) according to ANOVA one-way and Fischer's LSD post hoc analysis

Table 5. Cluster's characterization according to socio-demographics (only significative differences are marked with superscripts).

		All (N=104)	Cluster1 (N=39)	Cluster2 (N=38)	Cluster3 (N=27)	p-value
			Indulgence	Eatertainment	Tradition	
Gender (%)**	Female	64.4	59.0[b]	55.3[b]	85.2[a]	0.026
	Male	35.6	41.0[b]	44.7[a]	14.8[c]	
Age groups (%)	<25	43.4	41.0	44.7	44.4	0.650
	26-45	30.8	38.5	28.9	22.2	
	>45	26.0	20.5	26.3	33.3	
Nacionality (%)	Spain	88.5	79.5	94.7	92.6	0.165
	European	58.0	7.7	2.6	7.4	
	Latioamerican	5.0	12.8	2.6	0.0	
Education level (%)	Low	5.8	0.0	7.9	3.7	0.576
	Middle	61.5	24.0	65.8	55.6	
	High	34.6	38.5	26.3	40.7	
Monthly income (%)	Low (<1000 €)	43.2	43.6	47.3	37.0	0.087
	Middle (1000-2000€)	29.8	28.2	39.5	18.5	
	High (> 2000€)	19.2	20.5[ab]	7.9[b]	33.3[a]	
	NA	7.7	7.7	5.3	11.1	
Partnership life (%)	Along	7.7	15.4	2.6	3.7	0.515
	In couple	23.1	23.1	26.3	18.5	
	In family	49.0	41.0	52.6	55.6	
	Shared apartment	19.2	17.9	18.4	22.2	
	NA	1.0	2.6	0.0	0.0	
Sweet Tooth (%)**	Yes	78.8	84.6[b]	86.8[a]	59.3[c]	0.024
	No	21.2	15.4[a]	13.2[a]	40.7[b]	
Age*		34 (14)	33(13)[a]	34(14)[a]	35(14)[a]	0.803
BMI*		24(3)	24(3)[a]	24(3)[a]	23(2)[a]	0.187
Subjective hunger level at the start of the experiment * (scale 1 "not hungry" to 7"very hungry")		3.5 (1.6)	3.3 (1.5)[a]	3.7 (1.6)[a]	3.5 (1.5)[a]	0.827

*Mean (SD). Similar superscripts in the same line means a no significant difference (P < 0.05) according to ANOVA one-way and Fischer's LSD post hoc analysis
**Different lower cases in the same line mean a significant difference (P < 0.05) according to Chi-square in k proportions test.