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Virtual reality environments on the sensory acceptability and emotional responses of no- and full-sugar chocolate

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Abstract

Eating is a multimodal sensory experience affected contextual situations. A limitation with traditional consumer testing is that isolated booth environments lack ecological validity and consumer's engagement in forming perceptions. Virtual reality (VR) is an emerging method to simulate different environmental contexts. The acceptability and emotional responses of full- and no-sugar chocolate determined in sensory booths and under two VR environments (headsets) were evaluated. Untrained participants (N=50) tasted two chocolates (FS=full-sugar and NS=no-sugar, maltitol) under three environments: (1) traditional-booths, (2) positive-VR [aesthetically open-field forest], and (3) negative-VR [closed-space old room] in a 3×2 randomized-factorial-design. Participants rated the acceptability of sweetness, bitterness, texture, mouth-coating, aftertaste, and overall liking (9-point scale). The intensities of sweetness, bitterness, and hardness (15-cm line-scale) were assessed. Chocolate type and VR did not affect the liking of attributes (5.4-6.8). However, FS samples had higher sweetness intensity than NS samples for positive-VR (10.8 vs. 9.1). NS samples under positive-VR were associated with overall liking. The NS and FS samples under positive-VR were associated with "energetic" and "happy"; however, under traditional booths were related to "good", and "calm". "Bored" and "guilty" were associated with NS samples under negative-VR. VR can be used to understand the contextual effects on consumers' perceptions.

Keywords: Liking; immersive technology; valence; sensory booths; tasting

1. Introduction

The interaction between context and acceptability when consuming food and/or beverage products is affected by multiple sensory variables. The intrinsic (e.g., colour, aroma, taste, texture, and flavour) and extrinsic (e.g., label, packaging, country of origin, and price) attributes of foods and/or beverages, preparation/cooking methods, and consumption environments are interrelated to constitute the overall sensory experience of tasting (Liu, Hannum, & Simons, 2019). Contextual factors such as the eating location (Delarue & Boutrolle, 2010), ambient temperature and humidity (Bangcuyo, Smith, Zumach, Pierce, Guttman, & Simons, 2015) and sound/lighting (Kasof, 2002) can affect the liking and preferences of consumers. Collectively, this contextual information relates to the visual, auditory, olfactory, and gustatory dynamics of the stimuli. Contextual cues can shape the subsequent hedonic assessment, perception, purchase intention, and other food-related behaviours exhibited by consumers (Bangcuyo et al., 2015).

Every year, food and beverage companies invest heavily in consumer sensory research to launch new products. However, only a few of these products succeed in the marketplace based on the sensory data. The inability of consumers' methodologies to predict the food-related behaviours and purchase decisions is the main factor that contributes to the high failure rates in the marketplace (Gunaratne et al., 2019). In traditional sensory testing panels, participants generally are placed in isolated tasting booths located in a sensory laboratory facility (Lawless & Heymann, 2010). Such testing conditions are designed to control against the effects of non-product factors such as the external aromas, light distractions, and noises of various surrounding environments. However, some researchers have argued that this setting (individual booths) does not represent the actual conditions in which consumers taste their products (Jaeger & Porcherot, 2017). Highly controlled testing conditions may lack meaningful contextual information and ecological validity that can lead to a biased evaluation of the sensory attributes by the consumers (Liu et al., 2019; Bangcuyo et al., 2015).

The absence of consumers' engagement is also a factor causing the poor predictability rates of acceptability generated by the traditional testing conditions of sensory laboratories (Hannum & Simons, 2020). Bangcuyo et al. (2015) argued that some participants might feel bored and uninterested in quiet testing environments, resulting in biased responses of participants. Therefore, ratings of sensory attributes gathered under this context cannot accurately predict the food-related behaviours of consumers (Meiselman, Johnson, Reeve, & Crouch, 2000). Previous studies have found significant differences in food preference and purchase decisions under different testing environments (Jaeger & Porcherot, 2017). Consequently, it is necessary to develop new testing protocols to improve the predictability and reliability of consumers' sensory data. One alternative methodology is to perform "on-site" sensory evaluations. However, there are some limitations in conducting sensory tests in actual or practical contextual environments (e.g., cafeterias, restaurants, living rooms, or other external surroundings). In most cases, conducting sensory research in external locations is not feasible because it can be generally time-consuming and expensive (Meilgaard, Civille, & Carr, 1999).

Food and beverages are always consumed in a social context, full of congruent or incongruent elements, which may prove beneficial and detrimental to the eating experience. Indeed, the social context affects not only eating experience, but it also influences our food choices, rate, or amount of consumption and hedonic experiences (Spence & Shankar, 2010). These crossmodal congruency benefits (Kantono, Hamid, Shepherd, Lin, Skiredj, & Carr, 2019; Kantono, Hamid, Shepherd, Yoo, Carr, & Grazioli, 2016; Reinoso-Carvalho et al., 2020), i.e., crossmodal sensory assimilations, are of enormous interest to sensory scientists, and growing literature around this topic can be seen as a witness. Several crossmodal interactions, such as taste and colour (Spence, 2019); taste and acoustic (Kantono et al., 2016; Reinoso-

Carvalho et al., 2020; Spence & Shankar, 2010); taste and odour (Arvisenet et al., 2019) have been reported in the literature, and most of them speculating *emotions* role, at some level, in crossmodal mechanisms (Kantono et al., 2016; Reinoso-Carvalho et al., 2020). Emotional states induced by context could be stimulus-based, perceiver-based contexts or cultural contexts (Barrett, Mesquita, & Gendron, 2011), but only stimulus-based contexts may be important to partly explain the cross-modality causality (Kantono et al., 2016), such as enhancement of sweetness by vanilla essence. The impact of these emotional states on cognition and behaviour led to the development of mood induction procedures (MIPs) (Martin, 1990), which explicitly designed to provoke specific transitory affective states under controlled circumstances (Baños, Etchemendy, Castilla, Garcia-Palacios, Quero, & Botella, 2012; Felnhofer et al., 2015), and the use of virtual environments as MIPs has been echoed previously (Felnhofer et al., 2015). Immersive VR is a computer simulation that situates consumers in nearly real, true-to-life, emotionally charged environments (Jaeger, Hort, Porcherot, Ares, Pecore, & MacFie, 2017). VR can be used to create virtual surroundings and simulate actual contextual environments to improve consumers' engagement and ecological validity of sensory tests (Liu et al., 2019; Bangcuyo et al., 2015). This technology may facilitate the food and beverage industry to launch new products into the marketplace with higher success (Hathaway & Simons, 2017). However, there is a vast and unexplored area in the applications of VR technology towards the realm of food and/or beverage products. VR can be considered a controlled experimental condition in laboratory settings, but the outcomes in these naturalistic situations need to be further studied (Liu et al., 2019).

The overall objective of this research was to evaluate the sensory acceptability and emotional responses of full- and no-sugar (maltitol) chocolate in traditional sensory booths and under two different VR environments (positive and negative environments using headsets). Maltitol, a non-carcinogenic alternative sweetener with almost 50% of the calories of sugar, is widely used in sugarless confectionery (Son et al., 2018). Chocolate was selected as the food model for this experiment due to the proven characteristic of this product to elicit a greater variety of emotions compared to other foods (Cardello et al., 2012). A no-sugar version of the chocolate was used because of the current consumers' demand for reducing sugar in their diets due to the worldwide prevalence of obesity, diabetes, and cardiovascular diseases (Galland, 2013). It is expected to have specific sensorial differences between these products due to the change in the sweetening ingredient. Moreover, consumers are more interested in food products related to certain health benefits (Karelakis, Zevgitis, Galanopoulos, & Mattas, 2020). This research aims to understand the effects of contextual information in the shaping of the hedonic responses under different VR testing conditions, as well as the effects of VR on the emotional responses towards the chocolate products. Overall, results from this work can be useful for the global understanding of the context in the sensory assessments of food products. Novel immersive technologies are becoming more relevant in the study of consumer engagement and emotional connections with foods. Therefore, this work provides valuable insights to evaluate behaviours under different contextual changes.

2. Materials and Methods

2.1 Participants

The research protocol for this study was listed as minimal risks with the ethics approval 1543704.2 obtained in February 2017 by the Human Ethics Advisory Group (HEAG) of the Faculty of Veterinary and Agricultural Science at The University of Melbourne, Australia. A total of N = 50 participants (15 male and 35 female) ranging in age from 18 to 50 years old were recruited voluntarily for this research from a pool of faculty staff and students from The University of Melbourne. A power analysis was run on the sensory attributes yielding values of 77-80%. Therefore, the probability of Type II error in this experiment is relatively low

(~20%) for this type of consumer' assessments. All participants were untrained and reportedly not allergic to any food product. Participants who consumed chocolate products at least once per month were pre-selected for the sensory sessions. After a brief explanation of the sensory procedures, all participants were asked to sign a consent form approved by the Human Ethics Advisory Group (The University of Melbourne) before the tasting of the products. Sessions were conducted at the sensory laboratory facilities of The University of Melbourne. Participants were asked to refrain from eating, drinking, or smoking for at least one hour prior to the tasting. Three sensory sessions were conducted on three different days (one session using the booths and two sessions using the VR environments). The order of the sessions was randomized within each participant. The duration of one sensory session was approximately 20 to 30 minutes for each participant.

2.2 Stimuli

Two types of chocolate with different sweeteners were used for this study: Lindt™ Milk Chocolate No Sugar Added, and Lindt™ Excellence Milk Chocolate Extra Creamy (Lindt & Sprüngli Company, Zürich, Switzerland). For the results and discussion of the present study, the Lindt™ Milk Chocolate with no sugar added (sweetened with maltitol) was referred as the no-sugar sample (NS), and the Lindt™ Excellence Milk Chocolate containing 50% sucrose was referred as the full-sugar sample (FS). Both chocolate samples were purchased from a local grocery store throughout the development of the three testing sessions. The chocolate samples were stored in sealed containers at 16 °C when they were not in use. Both samples were prepared on the same day as the testing sessions to prevent chocolate from becoming stale. The two stimuli (NS and FS) were preliminarily assessed by a focus group (N = 6) panel within the University of Melbourne to ensure that they were differed enough in certain sensory attributes (sweetness, bitterness, and hardness) to obtain discriminating hedonic results. These samples had a similar appearance to prevent participants from memorising the previous assessment of the chocolate samples. For the tasting session, each chocolate sample was placed in a translucent plastic cup with a 3-digit random code for identification. The chocolate samples were presented in a random order across all three testing environments (one session using booths and two sessions using VR) to prevent changes in the hedonic assessment from the order effects.

2.3 Sensory procedure

At the beginning of the tasting sessions, each participant received a brief explanation with instructions regarding the sensory testing procedures, the proper operation and wearing of the VR headset devices, and on how to answer the questions in the paper ballots. For all participants, three sensory sessions were conducted in three different days (one environment for each day). The order of the sessions was randomised within each participant. For each session, all the participants began by signing the consent forms. Then they were instructed to evaluate the chocolate samples in one of the three testing environments (booths, positive VR, or negative VR). For the VR environments, one participant at a time was tested using the VR headset in a focus group-type room located at the sensory laboratory facilities (Figure 1). Participants tasted both chocolate samples (NS and FS) in each session. The presentation of the samples was randomised, and a sequential monadic sample order was used within each participant. In the questionnaire, participants were asked to rate the acceptability of the sweetness, bitterness, texture, mouth-coating, aftertaste, and overall liking of the chocolate samples using a 9-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely; Peryam & Pilgrim, 1957). The intensity of the sweetness, bitterness, and hardness were evaluated using a 15-cm unstructured line scale. Sweetness, bitterness, and texture were also evaluated using a just-about-right-scale (JAR; for sweetness and bitterness:

1 = too little, 2 = just-about-right, 3 = too much; for hardness: 1 = too soft, 2 = just-about-right, 3 = too hard). Purchase intent [Question: Would you purchase this product if it was commercially available in the marketplace?] of each chocolate sample was determined using a binomial scale (1 = Yes, 2 = No). A second purchase intent question was assessed after consumers were informed that the product was sugar-free [Question: Would you purchase this product knowing that this chocolate sample is sugar-free?]. To assess the elicited emotions of each chocolate sample, a check-all-that-apply (CATA) procedure was used with a list of 33 emotion terms (adventurous, satisfied, active, affectionate, calm, energetic, enthusiastic, free, friendly, glad, good, happy, interested, joyful, loving, merry, nostalgic, peaceful, pleased, pleasant, secure, warm, bored, disgusted, worried, aggressive, daring, eager, guilty, polite, steady, understanding, and wild) (King & Meiselman, 2010). These emotion terms were pre-selected from a list containing 48 emotional terms obtained from previous studies (Ng, Chaya, & Hort, 2013; Torrico et al., 2018) and research group discussions to cover two-dimensional affective spaces (valence and arousal) according to Bradley and Lang (1994). In between samples, participants used water and unsalted crackers to cleanse their palate.

2.4 Testing environments

Three testing environments were used for this study (traditional booths, positive VR, and negative VR). The traditional environment consisted of using individual and isolated booths located at the sensory laboratory facility at The University of Melbourne, Australia (Figure 1a). The dimensions of the sensory testing booths were 1.5 m (width) x 2.1 m (height) with a worktop for placing the samples and the questionnaires. A solid protection panel separated the adjacent testing station. The sensory booths were illuminated with modern LED lights (configured with colour white; RGB = 255, 255, 255). The temperature of the sensory booths room was set at 21 °C.

Consumer testing under the VR environments took place in a private and isolated focus-group room (Figure 1b). The VR environments were generated by a DELL visor mixed reality headset and controllers (DELL, Round Rock, TX, USA). VR headsets provided the static visual contextual cues. Both VR environment sceneries (positive and negative) used in this study were carried out by the Gala360 app (https://www.gala360app.com/, San Francisco, CA, USA). Gala360 app is an image collection gallery with high-quality panoramic photos for VR headsets. For this study, the VR headset was connected to a laptop PC (XPS, DELL, Round Rock, TX, USA) placed on a table in the testing room (Figure 1b). Two VR settings were chosen to elicit opposite emotional valances. The VR environments (positive and negative) were selected from a pool of 20 VR environments (Gala360) in preliminary focus group discussions (N=6). By doing this, the expected outcomes of this experiment was to generate positive and negative hedonic and emotional reactions of consumers while tasting the chocolate product. The chocolate samples and questionnaire were also placed on the table during the test. During the entire VR environment testing session, a testing supervisor was always present in the testing room to help participants with wearing the VR headsets and passing the samples to them when they had the headset on. After tasting, participants were instructed to remove the VR headsets and answer the questions related to the chocolate samples in the paper ballots.

The positive VR environment ("*Autumn in Blue Mountains*"; Gala360) was an aesthetically pleasing and open field environment (Figure 1c). The scenery represents a photo of the Blue Mountains located to the west of Sydney, NSW, Australia. This panoramic photo encompassed waterfalls and ponds, eucalyptus forests, bushwalking trails, and different species of plants. The weather reflected in this environment was sunny and clear, with a few clouds in the sky. The negative VR environment ("*The Glass House*"; Gala360) is a depressive and odd closed-space room (Figure 1c). The panoramic photo named "The Glass House" was taken at the "Imperfect Gallery" of Michael M. Koehler art installation in Philadelphia, USA (Gala360).

"The Glass House" was a room full of windows with old and mottled frames. The wooden floor was dirty and worn down. On the back wall, there were hanging pictures of animals and old houses. Withered plants and dark colour sculptures were placed on a windowsill. Next to the windowsill, there was an old phono-record player. Electric wires and plug-boards were exposed on the floor. For each VR exposure, two minutes were allowed for participants to experience the selected VR context while they were doing the sensory assessment of the chocolate product (Andersen, Kraus, Ritz, & Bredie, 2019).

2.5 Statistical analysis

For this study, a 3×2 factorial design (three testing environments and two chocolate samples) was used. Repeated measures analysis of variance (ANOVA) using participants as the blocks for this design, with a generalized linear model (GLM) and a *post-hoc* Tukey's Honestly Significantly Different (HSD) test were used to assess significant differences in the hedonic ratings and intensity scores of the chocolate samples under the three different testing conditions. The factorial experimental design implemented in this experiment allowed for measuring the effects of each independent factor (chocolate and environment), as well as the effect of the interaction. A penalty test on the JAR ratings was performed to determine the effects of the sensory attributes on the hedonic liking of the chocolate samples (Walker, 2017). The total penalty score (TPS) for individual attributes was calculated by multiplying the percentage of "not-JAR" (either "too little" / "too soft" or "too much" / "too hard") by the corresponding mean decrease [the difference between the liking score at "not-JAR" and the liking score at JAR]. For the CATA frequency data, Correspondence analysis and Principal coordinate analyses were used to assess the differences among the chocolate samples relative to selecting the emotion terms and overall liking levels. For the purchase intent, the Cochran's Q test and simultaneous confidence intervals testing were used for multiple comparisons. The

McNemar test was used to determine statistical differences in purchase intent before and after the "sugar-free" information was provided to the consumers. A Principal Component Analysis (PCA) was applied to interpret relationships between the hedonic ratings and intensity scores of the chocolate samples at different testing conditions. A product-attribute biplot was used for the illustration of the PCA. Hierarchical Cluster Analysis (HCA) was performed using the Euclidean distance, and the Wards linkage to categorise sample groups that were similar in the sensory results. Data were analysed at $\alpha = 0.05$ using the XLSTAT Statistical Software version 2017 (Addinsoft, New York, NY, USA). All data were reported as mean values with standard errors.

3. Results

3.1 Sensory responses to chocolate samples under different environments

Table 1 shows the ANOVA results for the different sensorial parameters (acceptability and intensity) related to the treatment factors, including the type of chocolate (NS and FS), environment (negative VR, traditional booths, and positive VR), and the two-way interaction (chocolate*environment). For the acceptability parameters (sweetness, bitterness, texture, mouth-coating, aftertaste, and overall liking), none of the treatment factors was significant ($P \geq 0.05$) in the ANOVA model, except for the type of chocolate, which was associated to the liking of bitterness ($P < 0.05$). For the intensity parameters (sweetness, bitterness, and hardness), the type of chocolate was a significant ($P < 0.05$) factor in the ANOVA model; however, the environment and interaction (chocolate*environment) factors did not show significant differences ($P \geq 0.05$) for these attributes (Table 1).

Table 2 shows the mean values of the acceptability and intensity parameters for the two different chocolate samples under the three different environments. For all the sensory acceptability attributes, the scores did not significantly ($P \geq 0.05$) differ depending on the type of chocolate and the testing environment. However, the NS chocolate samples had similar ($P \geq 0.05$) acceptability scores than those of the FS chocolate samples for all the liking attributes (5.90-6.84 vs. 5.40-6.70, respectively). For the NS chocolate samples, the positive VR environment had similar ($P \geq 0.05$) acceptability scores than those of the traditional booths and negative VR environments for all the liking attributes (6.22-6.76 vs. 5.90-6.84). The mean values of the intensity parameters (sweetness, bitterness, and hardness) of the chocolate samples under different environments are shown in Table 2. For the sweetness intensity, the FS chocolate samples had significantly ($P < 0.05$) higher scores compared to those of the NS chocolate samples under the positive VR environment (10.82 vs. 9.08, respectively). However, the sweetness intensity scores (9.41-10.41) between the NS and FS chocolate samples were not significantly ($P < 0.05$) different under the other environments (booths and negative VR). The NS chocolate samples had similar ($P \geq 0.05$) bitterness and hardness intensity than those of the FS chocolate samples (3.45-4.15 vs. 2.61-3.65 for bitterness and 6.93-7.15 vs. 6.24-6.41 for hardness, respectively, Table 2). The VR environments (positive and negative) did not significantly affect the bitterness and hardness of the chocolate samples.

Figure 2 (on the left side) shows the frequency distribution (%) of the participant's responses over the intensity of sweetness, bitterness, and hardness using the just-about-right (JAR) scale. This methodology is useful to identify the optimum intensity of sensory attributes using consumer' panels. JAR scales are used as a diagnostic tool to understand whether the products are lacking or exceeding the intensities of some critical attributes (Ares et al., 2017). The FS chocolate samples had a higher selection of "too much" sweetness than the NS samples (48-64% vs. 34-46%, respectively). In general, the NS samples had a higher JAR sweetness selection compared to that of the FS samples (46-62% vs. 36-48%, respectively). The selection of "too little" sweetness was negligible for all chocolate samples (0-8%). In general, all samples were perceived as "too little" in bitterness (54-84%). However, the NS chocolate samples had a higher JAR bitterness selection than the FS samples (36-44% vs. 16-26%). For all chocolate samples, the selection of "too much" bitterness was negligible (0-4%). For hardness, all chocolate samples had higher JAR scores compared to those of "too much" and "too little" (84-92% vs. 2-12%). Total penalty scores in the overall liking of the chocolate samples according to the JAR deviations of sweetness, bitterness, or hardness are illustrated in Figure 2 (on the right side). According to Walker (2017), attributes with penalty scores greater than 0.5 can potentially affect consumer acceptability. All the FS chocolate samples under the three environmental conditions (booths, positive VR, and negative VR) were strongly penalised for being too sweet (TPS = 0.59-0.74). However, the NS sample was strongly penalised for being too sweet (TPS = 0.62) only under the condition of the traditional booths. None of the chocolate samples (NS and FS) were penalised for being "too little" or "too much" in bitterness or hardness under all three environmental conditions (booths, positive VR, and negative VR; Figure 2).

3.2 Emotions, purchase intent and multivariate analysis of chocolate samples under different environments

Figure 3 shows the correspondence analysis of the stimuli category in relation to the emotion terms of the CATA questions. The principal component one (PC1) and principal component two (PC2), accounted for 57.17% and 18.29%, respectively, explaining a total of 75.46% of data variability. The correspondence analysis showed that the NS and FS chocolate samples under the positive VR environment were associated with positive emotional descriptors such as "energetic", "merry", "loving", "active", "happy", "glad", "pleasant", "free" and "friendly". On the other hand, for both chocolate samples (NS and FS) under the condition of the traditional booths, the emotional descriptors were related to more neutral emotions such as "calm", "satisfied", "secure", "warm", "pleased" and "polite". "Interested", "bored", "guilty", and "understanding" emotional terms were associated with the NS chocolate samples under the negative VR environment. For the FS chocolate samples under the negative VR environment, the emotional descriptors were related to passive feelings such as "worried", "eager", "aggressive", "wild", and "nostalgic" (Figure 3). The principal coordinate analysis of the emotion terms for both chocolate products (NS and FS) in relation to the overall liking scores is shown in Figure 3. In general, the liked products (overall liking scores >5.0) were associated with "warm", "nostalgic", and "active" emotional terms. On the other hand, the disliked products (overall liking scores ≤5.0) were related to "adventure", "interested", and "merry" emotional descriptors (Figure 3).

The original (before claiming the absence of sugar) purchase intent values of the NS chocolate sample were not different ($P \geq 0.05$) than the values of the FS chocolate samples under all three environmental conditions (44-72% vs. 42-52%, respectively; Table 3). Likewise, the chocolate samples (NS and FS) showed slightly (but not significant) higher original purchase intent values under the positive VR compared to those values under the booths and negative VR (52-72% vs. 42-52%, respectively, Table 3). The purchase intent of the NS chocolate samples under all three environmental conditions improved significantly after the absence of sugar content information was provided to participants (from 44-72% before to 64-80% after; Table 3). Similar to the original purchase intent, the NS chocolate samples showed a slightly (but not significant) higher purchase intent (after claiming the absence of sugar) value under the positive VR compared to those values under the booths and negative VR (80% vs.64-70%, respectively, Table 3).

For understanding the holistic relationship of all the measured variables (hedonic responses and intensities) combined with the difference among the samples, a multivariate approach was used. For both chocolate samples (NS and FS) under the three environmental conditions (positive VR, booths, and negative VR), the Principal Component Analysis (PCA) and

Hierarchical Cluster Analysis (HCA) results are shown in Figure 4. The PCA biplot explained 87.45% (PC1 = 67.17% and PC2 = 20.28%) of the total data variability, considering all the acceptability and intensity sensory parameters. The sweetness and bitterness liking vectors (factor loadings = 0.92-0.95; data not shown) contributed largely to the discrimination of both chocolate samples under all environmental conditions in the PC1. On the other hand, the bitterness intensity vectors (factor loadings = 0.90; data not shown) contributed largely to the discrimination of both chocolate samples under all environmental conditions in the PC2. According to the PCA, the liking scores of sweetness, bitterness, aftertaste, texture, and mouth-coating were positively associated with overall liking.

On the other hand, the bitterness intensity and liking of bitterness were positively associated with each other and negatively associated with the sweetness intensity (Figure 4). The NS samples under all environmental conditions were positively related to hardness intensity and liking of bitterness and were negatively associated with sweetness intensity. The opposite occurred with the FS chocolate samples under the positive VR and booths, in which these products were positively related to sweetness intensity and were negatively related to hardness intensity and bitterness liking. The FS chocolate sample under the negative VR was negatively associated with overall liking (Figure 4). Figure 4 shows the HCA of the six chocolate samples (2 types of chocolate x 3 environmental conditions) considering all acceptability and intensity variables. Three main cluster groups were formed: (1) NS samples under all environmental conditions, (2) FS samples under the negative VR, and (3) FS samples under the positive VR and traditional booths.

4. Discussion

No effect of context type on the sensory acceptability parameters of chocolate could be due to various reasons, such as irrelevant context type, higher product-to-context effect ratio, the higher indulgent effect of chocolates, or strong preference effect (Kong et al., 2020). Similarly, no effect of chocolate type on acceptability parameters could be due to many reasons, such as no stark difference between selected samples, poor signal-to-noise ratio, high sensory threshold of involved participants, attention-bias, and others. Similar findings have been reported previously, where social elements were found not affecting the chocolate eating experience (Kong et al., 2020; Pound, Duizer, & McDowell, 2000). Positive emotions elicited by congruent environment type may affect not only hedonic decisions but also perceived taste and food experiences, such as one observed here where a positive environment and subsequent positive emotions enhanced perceived sweetness. These kinds of sensation transference effects (Cheskin, 1972) have been noticed previously, such as smile enhanced pleasant feelings (Suzuki, Narumi, Tanikawa, & Hirose, 2014), curved shapes enhanced sweet sensitivity (Liang et al., 2016), and congruent music type enhanced sweetness (Wang, Woods, & Spence, 2015). While the underlying mechanism of this taste modulation is not known yet, few authors echoed the role of emotions in the causal mechanism (Kantono et al., 2016; Reinoso-Carvalho et al., 2020; Wang & Spence, 2018). In this study, the positive VR environment was found associated with favourable emotional terms, including “merry”, “loving”, “joyful”, “happy”, and “glad”. Participants may involve in transferring these emotions to the sample that they happen to the tasting (Wang & Spence, 2018). The pleasantness of the eating environment can positively affect the sensory perception and emotional responses of consumers (Sørensen, Møller, Flint, Martens, & Raben, 2003). Mood has a profound effect on how the world around is perceived for each person, and a positive mood appears to promote global, flexible, intuitive, and holistic information processing (Das, Deb, Adak, & Khan, 2019). On the contrary, negative moods have been associated with more systematic, focused, and analytic forms of processing (Das et al., 2019), which may be the reason for higher differentiation in the purchase intent under the booth and negative environment. The negative VR environment was found associated with negative self-elicited emotional terms such as “disgusted”, “guilty”, “bored”, and “nostalgic”. Consumers’ engagement during the sensory tests can be affected by the aesthetics of the environment, and the sensory characteristics and novelty of the product (Webster & Ahuja, 2006; O’Brien & Toms, 2008). The external environment can affect the expectation and experiences of consumers since behaviours can unconsciously be modified by several contextual factors (Oseland, 2009). In general, aesthetically pleasing environments can increase the emotional dimensions of arousal and valance, resulting in a potential increase in the engagement levels of consumers (O’Brien & Toms, 2010).

From the sweetener point, maltitol has been previously found less sweetening than ordinary sugar (Son et al., 2018). Sugar enhances the flavour profile of the chocolate by increasing the aroma of other flavours as well as balances the bitterness often associated with cocoa (Goldfein & Slavin, 2015). Sucrose alternatives generally cannot reproduce the physical properties that sugar brings to the chocolate processing, such as mouthfeel and texture (Aidoo, Afoakwa, & Dewettinck, 2014).

In the present study, neither the type of chocolate nor the environments had any significant effect on the purchase intent of the products. However, the claim stating the absence of sugar in the product increased the purchase intent significantly of the NS chocolate samples under the traditional booths and the negative VR environments (Table 3). Humans are rational beings who make systematic use of the information available to them (Jiang et al., 2020; Kan & Fabrigar, 2017), and information regarding the healthy benefits of alternative sweeteners, such as ‘no-sugar’ could be a motive here for high purchase intent. Similar findings have been noticed previously, where information profoundly affected purchase (Jiang et al., 2020). Consumers tend to increase their purchase intentions if the intrinsic properties of the food products are related to certain health benefits (Tarancón, Sanz, Fiszman, & Tárrega, 2014).

In summary, the observed lack of context effect via VR in chocolate eating experience needs further research to validate this finding, maybe through a home-use test or central lab testing. Nevertheless, the application of VR in the context validity scenario seems promising, in itself it is not free from hassles, just to name a few, such as mounting of VR masks the appearance of the samples, participants may need to go back-and-forth for processing, more of memory-based responses, the inherent visuals provided by the companies needs calibration for the purpose or if new real context being developed by the researcher for the natural eating occasion, and attention-bias to new environment, among others. Researchers need to establish a robust strategy to accommodate the aforementioned challenges for accuracy and precision.

5. Limitations

The VR environments were chosen to produce an effect of positive and negative valence, which may not be a favourable environment from the chocolate-eating context; hence readers are advised to consider this assumption when reading. The population sample size could be another limitation of this study. However, results from this experiment showed a strong connection of the consumers elicited emotions with the contextual environments using different VR setting. Due to the device limitations, the appearance was not assessed. Food appearance is a significant factor in the expectations of unfamiliar foods (Santagiuliana, Bhaskaran, Scholten, Piqueras-Fiszman, & Stieger, 2019). Favalli, Skov, and Byrne (2013) indicated that the combination of appearance and texture sensory attributes affect the overall conceptual understanding of foods. Currently, our lab is also exploring the use of augmented reality (clear visors), which can allow participants to directly look at the samples and, at the same time, experience the virtual surroundings.

6. Conclusion

The use of VR headsets can be one of the multiple options for incorporating immersive contexts into consumer evaluations. There is a very limited amount of previous studies that are exploring this topic. This research aimed to understand the use of VR environments on the acceptability, perception, and emotional responses of consumers towards chocolate products. One limitation of this study was that participants could not evaluate the appearance of the samples when they had the VR headsets on. This may be solved by using augmented reality (AR) headsets in future studies. Overall, the present study showed that VR environments affected the perception of sweetness and the emotional responses of consumers towards chocolate products. Future research should be conducted to explore the role that virtual reality and immersion play in creating contextual information in sensory evaluations.

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Figures captions

Figure 1 Experimental settings* for the sensory evaluation of chocolate
*(a) Traditional sensory booths, (b) VR set up, (c) frontal view of the positive VR environment, (d) lateral view of the positive VR environment, (e) frontal view of the negative VR environment, and (f) lateral view of the negative VR environment. VR environments were obtained from the Gala360 app (https://www.gala360app.com/).

Figure 2 Selection frequencies (%) of Just-About-Right (JAR) results and the total penalty scores in overall liking for sweetness, bitterness, and hardness of the chocolate samples*
*NS-PVR = No-sugar chocolate – Positive VR, NS-B = No-sugar chocolate – Traditional booths, NS-NVR = No-sugar chocolate – Negative VR, FS-PVR = Full-sugar chocolate – Positive VR, FS-B = Full-sugar chocolate – Traditional booths, and FS-NVR = Full-sugar chocolate – Negative VR. . Figure legend: ▤ = Too little, ▩ = Just about right, and : ■ = Too much.

Figure 3 (a) Correspondence analysis of the emotion terms for the chocolate samples in each environment* and (b) principal coordinate analysis of the emotion terms with the overall liking** score
*NS-PVR = No-sugar chocolate – Positive VR, NS-B = No-sugar chocolate – Traditional booths, NS-NVR = No-sugar chocolate – Negative VR, FS-PVR = Full-sugar chocolate – Positive VR, FS-B = Full-sugar chocolate – Traditional booths, and FS-NVR = Full-sugar chocolate – Negative VR. Figure legend: ● = Attributes, and ○ = Treatments.
**OL = Overall liking.

Figure 4 (a) Principal component analysis (PCA) bi-plot and (b) cluster analysis visualizing treatments* (chocolate samples in each environment*), acceptability (liking), and intensity attributes
*NS-PVR = No-sugar chocolate – Positive VR, NS-B = No-sugar chocolate – Traditional booths, NS-NVR = No-sugar chocolate – Negative VR, FS-PVR = Full-sugar chocolate – Positive VR, FS-B = Full-sugar chocolate – Traditional booths, and FS-NVR = Full-sugar chocolate – Negative VR.

Table 1 ANOVA* table for the acceptability and intensity parameters of the chocolate samples

Treatment effects*	Acceptability attributes (liking)					
	Sweetness		Bitterness		Texture	
	F Value**	Pr > F**	F Value	Pr > F	F Value	Pr > F
Chocolate	2.56	0.11	7.44	***0.01***	1.90	0.17
Environment	1.46	0.23	0.06	0.94	2.23	0.11
Chocolate*Environment***	1.38	0.25	0.94	0.39	0.25	0.78

Treatment effects	Acceptability attributes (liking)					
	Mouthcoating		Aftertaste		Overall liking	
	F Value	Pr > F	F Value	Pr > F	F Value	Pr > F
Chocolate	0.45	0.50	2.14	0.14	2.66	0.10
Environment	1.28	0.28	1.19	0.31	0.97	0.38
Chocolate*Environment	1.85	0.16	0.29	0.75	1.62	0.20

Treatment effects	Sensory attributes (intensity)					
	Sweetness		Bitterness		Hardness	
	F Value	Pr > F	F Value	Pr > F	F Value	Pr > F
Chocolate	17.19	***< 0.01***	4.93	***0.03***	6.07	***0.01***
Environment	0.06	0.95	2.23	0.11	0.14	0.87
Chocolate*Environment	1.00	0.37	0.16	0.86	0.03	0.98

*ANOVA = Analysis of variance [2 types of chocolate (no- and full-sugar samples) and 3 contextual environments (traditional booths, positive VR, and negative VR). N = 50 participants were used for the analysis. Liking scores were based on a 9–point hedonic scale (1 = dislike extremely, 9 = like extremely; Peryam & Pilgrim, 1957). Intensity scores were based on a 15-point Likert scale (1 = absent, 15 = strong for sweetness and bitterness, and 1 = soft, 15 = hard for hardness).

**F value, Mean square/Mean square error. Effects were considered significant when the probability Pr > F was less than 0.05 (Bolded and italicised probabilities).

***The type of chocolate effect was crossed with the environment effect in a 2-way factorial design (type of chocolate by environment).

Table 2 Acceptability and intensity mean values of the chocolate samples* in each environment

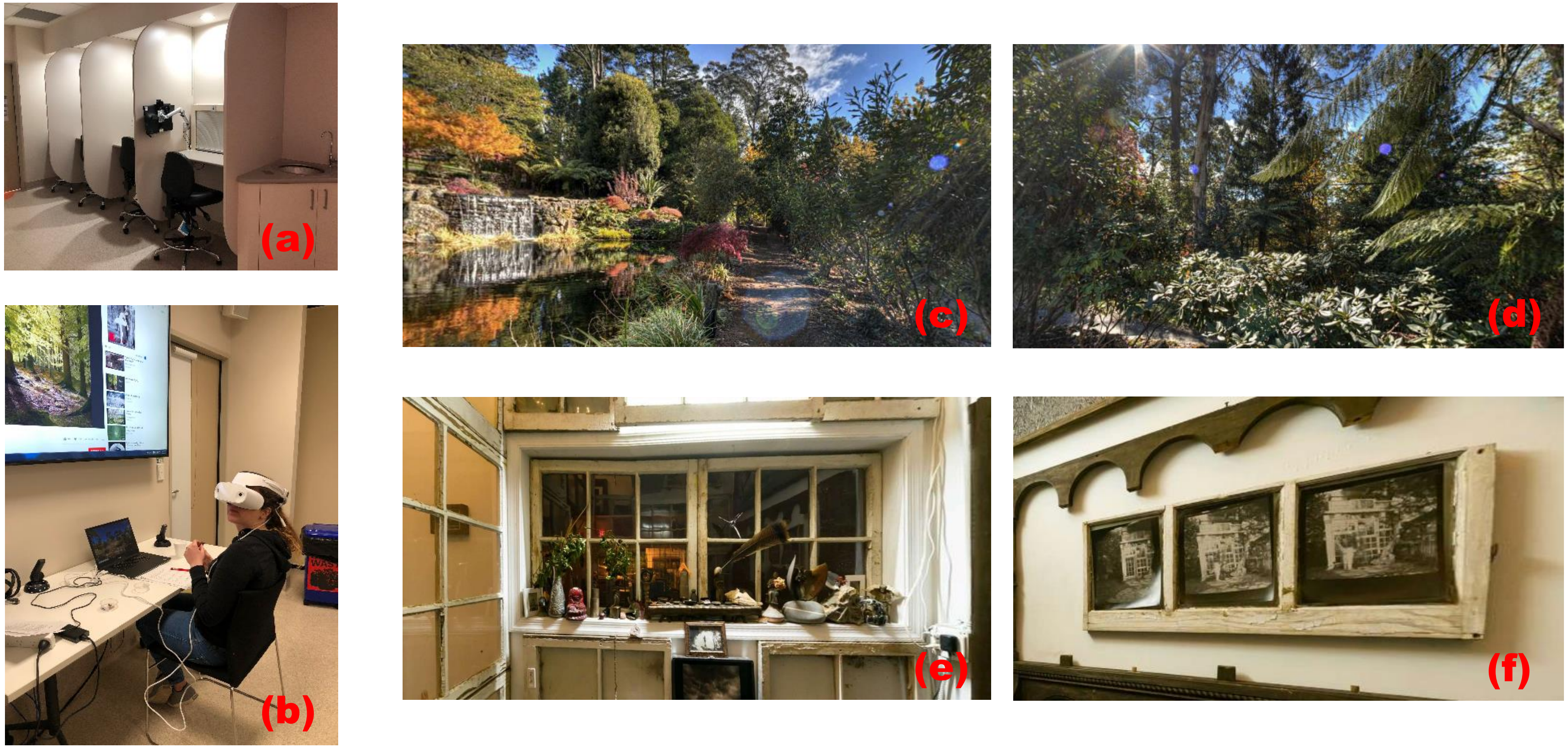
Treatment effects**		Acceptability attributes (liking)***		
Chocolate type	**Environment**	**Sweetness**	**Bitterness**	**Texture**
	Positive VR	6.60±0.26[a]	6.22±0.25[a]	6.74±0.19[a]
NS	Booths	6.16±0.26[a]	5.90±0.25[a]	6.84±0.19[a]
	Negative VR	6.04±0.26[a]	6.10±0.25[a]	6.40±0.19[a]
	Positive VR	5.86±0.26[a]	5.44±0.25[a]	6.38±0.19[a]
FS	Booths	6.28±0.26[a]	5.74±0.25[a]	6.66±0.19[a]
	Negative VR	5.64±0.26[a]	5.40±0.25[a]	6.30±0.19[a]
Treatment effects		**Acceptability attributes (liking)*** **		
Chocolate type	**Environment**	**Mouth-coating**	**Aftertaste**	**Overall Liking**
	Positive VR	6.70±0.21[a]	6.60±0.21[a]	6.76±0.22[a]
NS	Booths	6.36±0.21[a]	6.28±0.21[a]	6.22±0.22[a]
	Negative VR	6.46±0.21[a]	6.34±0.21[a]	6.48±0.22[a]
	Positive VR	6.42±0.21[a]	6.32±0.21[a]	6.26±0.22[a]
FS	Booths	6.70±0.21[a]	6.20±0.21[a]	6.38±0.22[a]
	Negative VR	6.06±0.21[a]	5.94±0.21[a]	5.96±0.22[a]
Treatment effects		**Sensory attributes (intensity)*** **		
Chocolate type	**Environment**	**Sweetness**	**Bitterness**	**Hardness**
	Positive VR	9.08±0.35[b]	3.82±0.42[a]	7.15±0.38[a]
NS	Booths	9.41±0.35[ab]	3.45±0.42[a]	7.13±0.38[a]
	Negative VR	9.54±0.35[ab]	4.15±0.42[a]	6.93±0.38[a]
	Positive VR	10.82±0.35[a]	2.87±0.42[a]	6.41±0.38[a]
FS	Booths	10.32±0.35[ab]	2.61±0.42[a]	6.28±0.38[a]
	Negative VR	10.41±0.35[ab]	3.65±0.42[a]	6.24±0.38[a]

*Two chocolate samples were tested [no- and full-sugar samples]. Means of 50 data points.
**Booths = traditional sensory booths, NS = no-sugar chocolate samples, FS = full-sugar chocolate samples, and VR = virtual reality (for the positive and negative environments).
***Liking scores were based on a 9–point hedonic scale (1 = dislike extremely, 9 = like extremely; Peryam & Pilgrim, 1957). Intensity scores were based on a 15-point Likert scale (1 = absent, 15 = strong for sweetness and bitterness, and 1 = soft, 15 = hard for hardness).
[a-b] Means with different superscripts in each column within each attribute indicate significant differences (*P* < 0.05) by the Tukey studentised Range (HSD) test.

Table 3 Positive purchase intent values of the chocolate samples* in each environment

Treatment effects**		Purchase intent before (%)***	Purchase intent after (%)***
Chocolate type	**Environment**		
NS	Positive VR	72%[a,A]	80%[a,A]
	Booths	52%[a,B]	70%[a,A]
	Negative VR	44%[a,B]	64%[a,A]
FS	Positive VR	52%[a]	-
	Booths	48%[a]	-
	Negative VR	42%[a]	-

*Two chocolate samples were tested [no- and full-sugar samples]. N = 50 participants.
**Booths = traditional sensory booths, NS = no-sugar chocolate samples, FS = full-sugar chocolate samples, and VR = virtual reality (for the positive and negative environments).
***Cochran's Q test and simultaneous confidence intervals testing were used for multiple comparisons among treatments. The McNemar test was used to determine statistical differences in purchase intent before and after the no-sugar information was provided to consumers.
[a-a] For the purchase intent results, percentage values with the same letter within the same column are not significantly different [$P \geq 0.05$; Cochran Q test and simultaneous confidence interval test].
[A-B] For the purchase intent results, percentage values with the same letter within the same row are not significantly different [$P \geq 0.05$; McNemar test].



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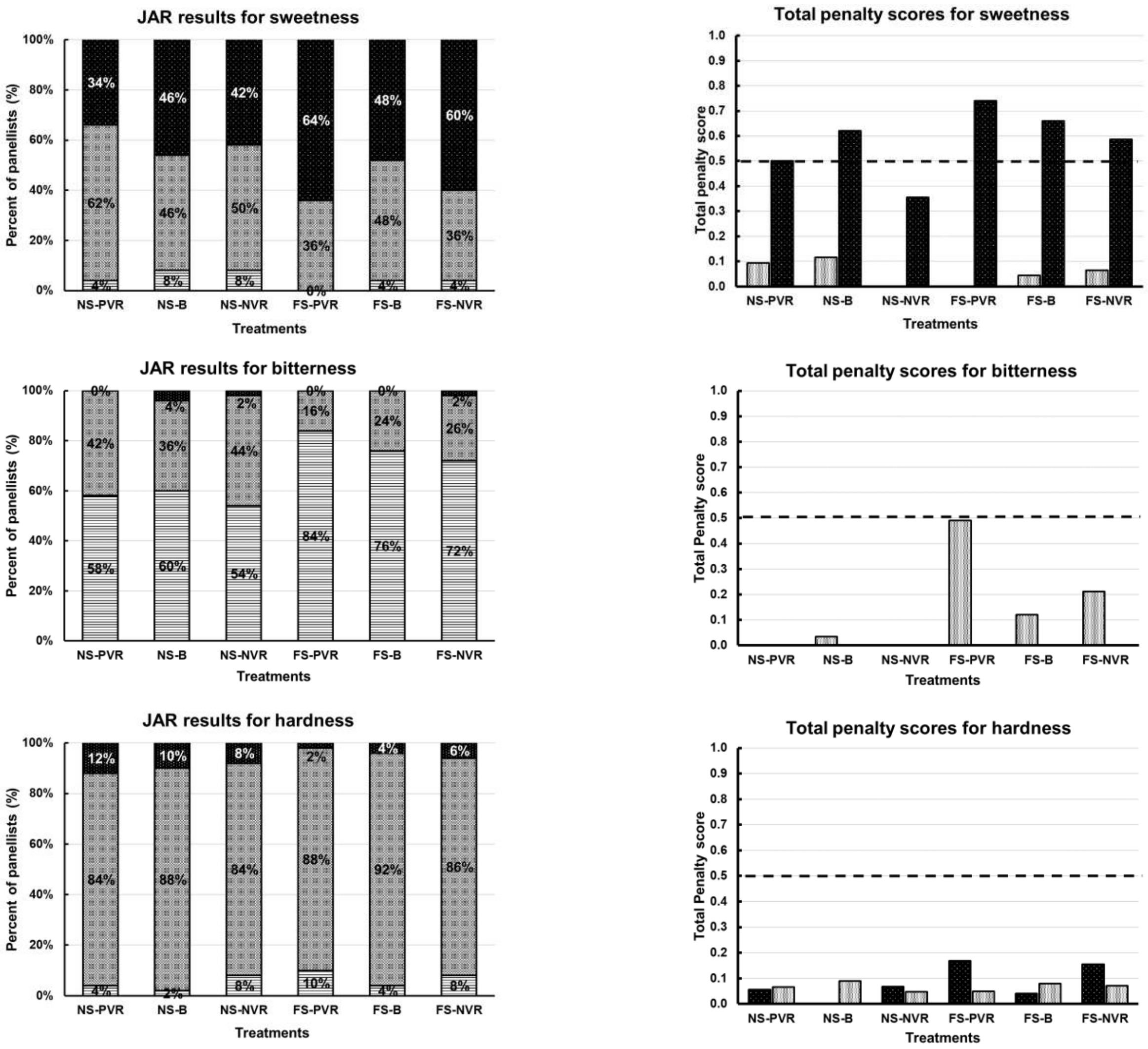

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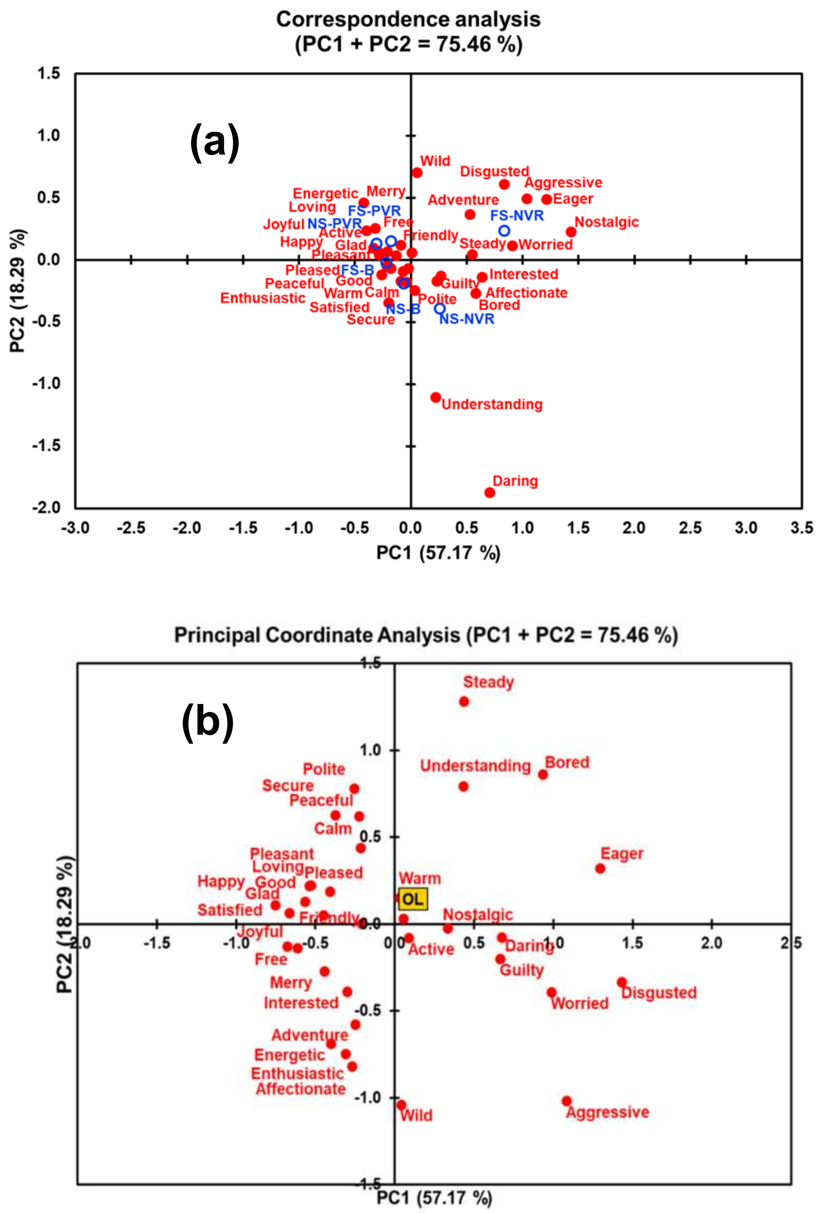

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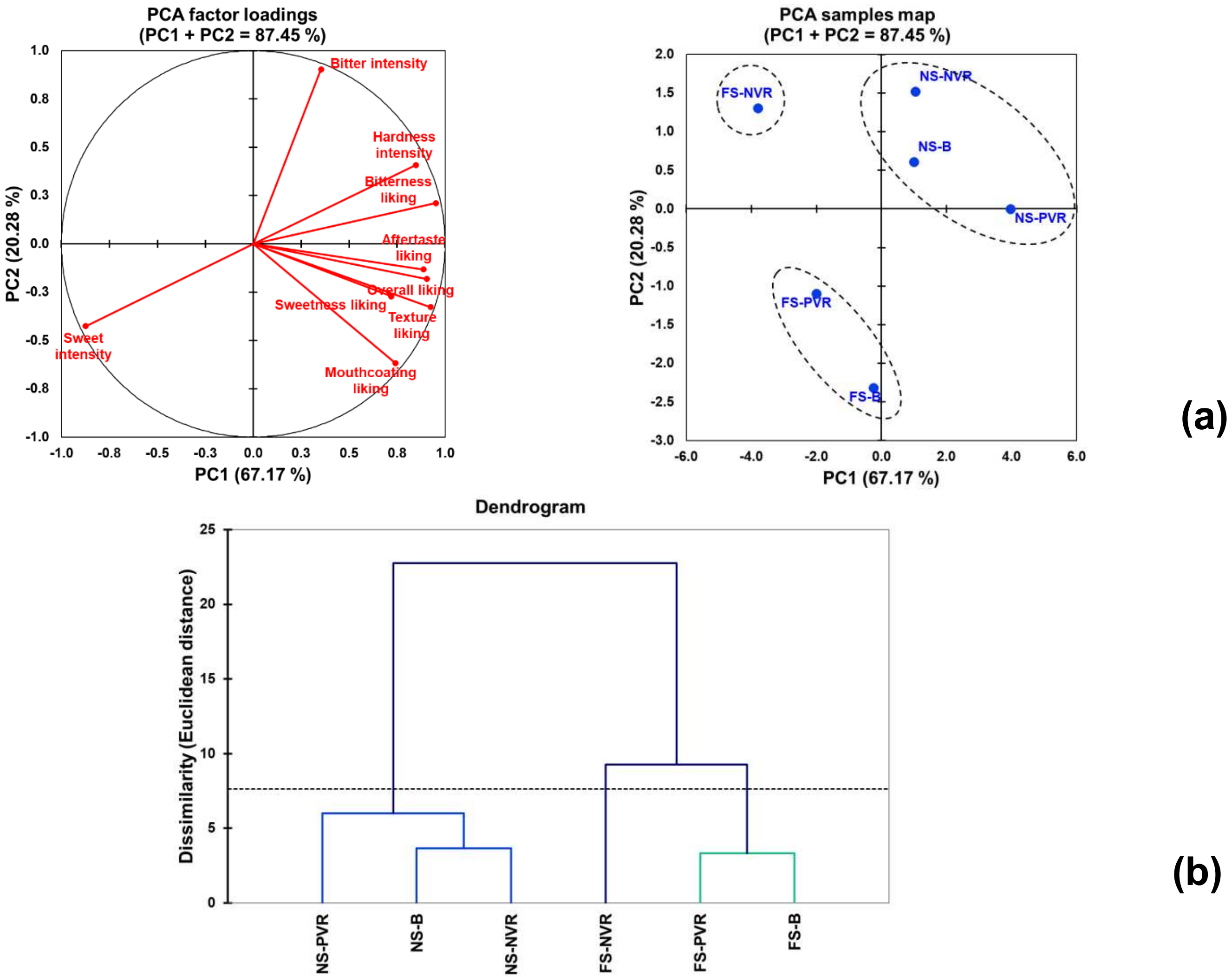

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