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**Aesthetic emotions in a mixed reality
multisensory experience with food crossmodally
matched to music and visuals**

Bruno Mesz¹, Jean-Christophe Sakdavong², Sami Silén³, Anu Hopia³

¹Universidad Nacional de Tres de Febrero (UNTREF). Instituto de Investigación en Arte y Cultura (IIAC). Juncal 1319, CABA, Argentina. E-mail: bmesz@untref.edu.ar

²Cognition, Languages, Language and Ergonomics Laboratory (CNRS UMR5263, Université de Toulouse), 5 Allées Antonio Machado, 31058 Toulouse Cedex 9, France

³Functional Foods Forum, University of Turku, Finland.

Aesthetic emotions in a mixed reality multisensory experience with food crossmodally matched to music and visuals

***Abstract.** We examine the emergence of aesthetic emotions in a mixed reality (MR) multisensory eating experience. Participants in an art-science event completed the AESTHEMOS questionnaire on aesthetic emotions and the Multimodal Presence Scale, reporting a wide spectrum of prototypical, pleasant and epistemic emotions. Food enjoyment was correlated with the prototypical aesthetic emotions of fascination and enchantment and feelings of self-presence were correlated with the prototypical emotions of being moved/in awe. Crossmodally matched food was highly congruent with music and visuals. Our findings indicate the relevance of studying environmental aesthetics in the context of these novel eating situations.*

Keywords: food experience, virtual reality, mixed reality, aesthetics, emotion

1. Introduction

The importance of emotions in food experiences is widely recognized and acknowledged. As described by Rozin [1] food, which is fundamental for existence, is both fun and frightening but also a far-reaching cultural phenomenon and an integral part of civilization. Therefore, it is not surprising that the interrelation between food experiences and emotions range from emotions produced by sensory pleasure to those of disgust when tasting food [2], and also include both the effect of emotions on eating behavior [3] and the effect of eating behavior on our emotions [4]. However, aesthetic emotions, i.e. the emotions that can arise when a person perceives and evaluates a stimulus for its aesthetic appeal or virtue [5] have hardly been investigated in connection with food experiences. For instance, only a few studies consider the aesthetic experience of eating in restaurants and its effect on food perception and enjoyment, going beyond the sensory and atmospheric aspects to consider aspects such as beauty [6]. In the present study, we examine the aesthetics of dining environments in mixed reality (MR), which are likely to grow in popularity in the near future.

1.1. VR and mixed reality food experiences

As researchers can use "Dark Dining" [7] to change consumers perception by neutralizing visual perceptions, it is possible to use Immersive Technologies in order to have more ecological studies. A definition of VR can be "an integration of several elements, including computers, worlds and environments, interactivity, immersion, and users, who are usually referred to as participants in a virtual reality experience." [8].

Augmented reality (AR) is a general term used to characterize experiences where the reality is augmented by supplementary information: it can be seen using a headset with comments inside a museum or through a projected display on the shield of a modern car. Usually, information brought by AR is simple, e.g. the speed of the car. Mixed Reality (MR) is a more modern term meaning that a part of the real world (in addition to the user) is mixed with the virtual world. The virtuality continuum from Milgram and coworkers [9] shows how virtuality and reality can be interlaced and Figure 1 is a revisited view of this virtuality continuum using food. This figure shows how we can include real foods (with their specific sensory properties: texture, smell and taste) in a virtual environment.

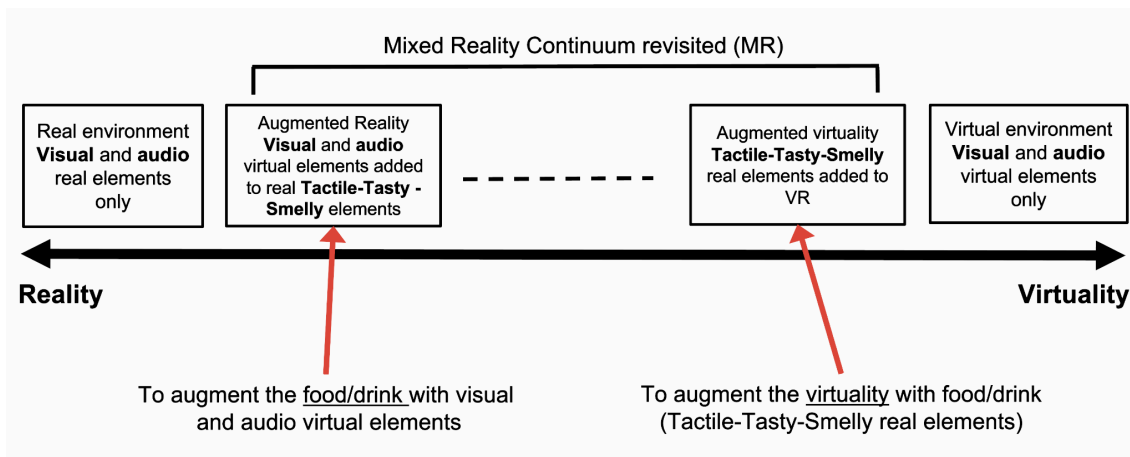


Figure 1. Virtuality continuum revisited.

Virtual reality (VR) started to be used in food related research a few years ago, with the first published studies dating back to the late 2010s, see e.g. Wang and coworkers [10]. The first application of VR was to replace sensory booths in sensory and consumer studies. The second step when using VR or MR for food experiences is to use them in order to change the perception of the food or its enjoyment. Two ways of doing this are altering the food aspect or changing the environment, for example, by changing the color of the food [11, 12], or altering the color, texture and shape of the environment [13].

Regarding the effects of sound combined with visuals, a recent study [14] demonstrated that cold brewed coffee tastes sweeter when consumed in a virtual environment with a pleasant color and music, compared to one with an unpleasant color and music. In addition, the study showed an interaction effect between color and music valence on coffee liking; positive music increased the liking ratings in the presence of a positive environmental color.

1.2. Presence and its measure

Presence is the feeling of being inside the displayed virtual environment [15-17]. This concept is widely used in studies where a user interacts with an immersive virtual environment using a virtual reality headset. Studies like Riva and coworkers [18] and Chirico and coworkers [19] have shown that presence in VR or 360° videos emerged as an amplifier for emotional responses.

Presence is also known as an important factor enhancing enjoyment in many activities such as video games. It is likely that this also holds true for VR/MR food

experiences. The concept of presence is multidimensional and researchers like Lee [20] or Makransky [21] use the concepts of physical presence (e.g. the sense of physical realism, the absence of attention toward the outside world, the non-awareness of physical mediation), social presence (e.g. the feeling of coexisting with other beings) and self-presence (e.g. the sensation of extension and prolongation of the body of the user in the avatar displayed in the virtual environment). Makransky [21] has developed the Multimodal Presence Scale in order to measure the three dimensions of presence according to Lee [20]: physical presence, social presence and self-presence. This three-dimensional scale is obtained using a questionnaire of 15 questions (5 questions per dimension).

1.3. *Gastrosonics* in Ubimus

Throughout history, food has been associated with music. However, only recently have researchers started to consider the impact of what we hear on the experience of eating and drinking, be it consumption sounds, soundscapes or music. Crossmodal correspondences between taste and sound have been used to modify the experience of many different food and drink products by changing the music or soundscape that people listen to. Crossmodal correspondences refer to the associations that many of us appear to make between seemingly unrelated attributes, features or dimensions in two or more different senses, as, in our case, taste and hearing [22]. Empirical research shows that sweet taste tends to be matched with sounds that are high in pitch, with slow-tempo legato music, soft dynamics, and consonant harmonies [23, 24]. By contrast, sour taste tends to be matched with extremely high-pitched sounds, fast tempo and dissonant music. Bitter taste is matched with sounds that are low in pitch and more likely to be brassy [25]. Salty taste is mostly associated with staccato music [23]. Importantly, these preferred pairings of taste and sound, when presented together, tend to enhance the pleasure of what one is tasting.

In the context of Ubimus there has been a recent upsurge of interest in investigations on the interactions between technology, music and gastronomy, a field for which Ubimus researchers have proposed the name *gastrosonics*. This has led to several publications and a special dossier on “Ubimus, Gastrosonics and Well-Being” in the *Vórtex Journal* [26]. For instance, in [27], Keller et al. report a preliminary study using drinks prepared at home as triggers for sonic choices. The basic sonic materials included sounds that were previously classified as corresponding to various tastes, or as neutral. The task was to create a sonic mix with segments subjectively congruent to each drink; this was done in a collaborative fashion among small groups of participants. To facilitate the interchanges, which were remote due to the pandemic, the SoundSphere environment was used [28] and augmented with *gastroicons* depicting the beverage associated with each basic material by the participant who added it to the mix. As it turned out, participants were able to carry these collaborative compositions using SoundSphere and there was a tendency to match the intended “taste” of the sonic materials selected with the flavor of the beverage that prompted the choice. In [29], Mesz et al. report a gastrosonic commensality experience for three guests, called *Quorum Sensing*, that was inspired in a nonhuman sense by which bacteria detect the presence of other microorganisms. A soup was served in a glass tableware, and the actions of each diner with the spoon produced vibrations applied to the body of the others, varying in intensity depending on the rate of movement of the spoon. The tableware itself was designed as a result of a research project on associations of shapes and materials with

musical emotions, and had inserted digital tablets showing abstract fermentation landscapes. Still another example is the system “Taste this score” of Rosales [30], where the composer elaborates a videoscore including visual textures of food, proposing the realization of sonic dinners by making scores from the visual textures of each dish and interpreting them to enrich the eating experience.

1.4. Aesthetic emotions in MR food experiences

It was the aim of this study to examine the impact of environmental aesthetics, feelings of presence and perceived congruence between environment and food on aesthetic emotions and food enjoyment in a mixed reality (MR) multisensory eating experience. The experience was divided in two clearly differentiated parts (A and B). In Part A food was more standard and familiar (Gouda cheese and Malbec wine), the aspect of the food was realistically represented in VR, and participants remained seated when eating and drinking. In contrast, in part B the food was elaborated to be crossmodally correspondent with the visuals, music and simulated temperature of the environments, its appearance was disguised as small “planets” which moved in space and participants were induced to stand up and turn around to pick the food and contemplate the environment. So essentially the main difference between parts A and B was the familiarity/unfamiliarity of the food aspect and behavior, and the use of crossmodal correspondences to design the food in part B.

We can summarize our main findings and conclusions as follows:

- Mixed reality food experiences can elicit a wide spectrum of aesthetic emotions
- The mixed reality food experiences mostly had positive valence and the subclass of negative aesthetic emotions was scarcely represented
- Most participants experienced feelings of beauty
- Food enjoyment was correlated with emotions of fascination and enchantment
- In Part B, congruence of crossmodally designed food with music and visuals was high
- In Part B, unusual looking food that moved around in space was highly enjoyed, suggesting applications of MR to overcome food neophobia and helping people to accept special diets by changing food aspect and environment

2. Materials and Methods

2.1. Participants

Twelve volunteers (3 males, 9 females, aged from 26 to 66 with a Mean age of 41.9, and an SD of 13.6) participated in the study. Due to the assembly restrictions during the Covid pandemic they were participants by invitation to the art and science event “Do science, art and technology spice up future food experiences?” and they represented the employees of the University of Turku.

2.2. Stimuli

Participants were supplied with an Oculus/Meta Quest 2 VR headset. The whole MR experiment was developed with Unity3D thanks to the AD2RV non-profit association - see web reference Food Experiment Turku December 2021 [31]. During the whole experiment, the participant was seated in front of a real table with a dish with cheese

cubes, a 3D printed glass of wine and a shelf with balls of food (Cf. Figure 2a). The cheese samples were of a mild gouda-type cheese (Brandy-pähkinä by Juustoportti Ltd., Jalasjärvi, Finland) and the wine organic Alamo Malbec 2020 from the Mendoza region, Argentina.

In Part A, the virtual reality showed the same table, dish, cheese and glass of wine as in the real world. When the participant was not touching the food, the background was black. When the participant touched the food, 360° videos were displayed as a background. This visual background was designed by the Dutch-Argentine artist Rob Verf [32, 33]. He produced two 360° videos inspired by the microbial fermentation landscapes of cheese and wine. These videos were triggered by the action of taking hold of a piece of cheese or a glass of wine, respectively, and continued for 20 seconds after this action (in the case of cheese) or after the glass was placed back on the table (for the wine). The appearance of the food and wine were designed by Jean-Christophe Sakdavong with the help of the AD2RV non-profit association using Unity 3D and Liquid Volume pro 2 assets. The location of the 3D printed glass of wine and the cubes of cheese was precisely mapped in order to have a perfect synchronization between virtual reality and the real world. The glass was designed in order to lower finger occlusion while the glass was being held.

In Part B, “Planets of Fire & Ice”, the visual background represented imaginary cold and hot outer space environments. The environments and appearance of the foods were designed by Jean-Christophe Sakdavong, with AD2RV. Realistic effects pack 3, AOE magic spells, Aura and ground effects were used. The food for Part B were cold chocolate balls and warm cheese balls described in the supplementary material (S1). In the VR/MR installation the food balls (“the planets”) were placed on a specially designed shelf with 3D printed spoons, which were precisely mapped in order to have perfect synchronization between virtual reality and the real world.

A video showing the environments and interaction can be found at

 [Food Experiment TURKU December 2021](#)

2.2.1 Crossmodally matched music

During Part A, when the 360 videos were not active, soft conversation noises were played. When the cheese-related video was active in the background, the music combined electro-acoustical processed sounds of kombucha fermentation intended to be semantically related to the microbial world (the sounds had been previously played and its origin explained to the audience during the event) and to create a feeling of weirdness, mixed with soft, legato consonant chords related to the dominant emotion and sensory attributes of Gouda cheese: pleasantness, softness and creaminess [34]. When designing these chords, taste pleasantness was associated with psycho-acoustic pleasantness (consonance), texture softness with soft sound dynamics, and creaminess with legato [35]. In contrast, when the wine was taken and the wine-related video was playing, the music consisted of a melancholic sound texture to match an aged red wine. In Part B, when the "cold deep space" environment was present, the music was composed of a high-pitched strong wind sound and high-pitched dissonant chords, reflecting cross-modal correspondences of coldness with high pitch [36]. Moreover, a sound texture of breaking ice was synchronized with the act of taking the cold eucalyptus-menthol-chocolate balls with a rough surface and crunchy texture. This music, together with the visuals, transitioned to a "hot deep space" environment, populated by a low-pitched bubbling sound, a soft low-pitched wind and cross-modal

congruent medium-pitched chords [37]. A sizzling sound in a frying pan was synchronized with the taking of the warm jalapeño cheese balls.

The music was designed by Bruno Mesz and Sami Silén; sounds of fermentation were recorded with two large diaphragm microphones.

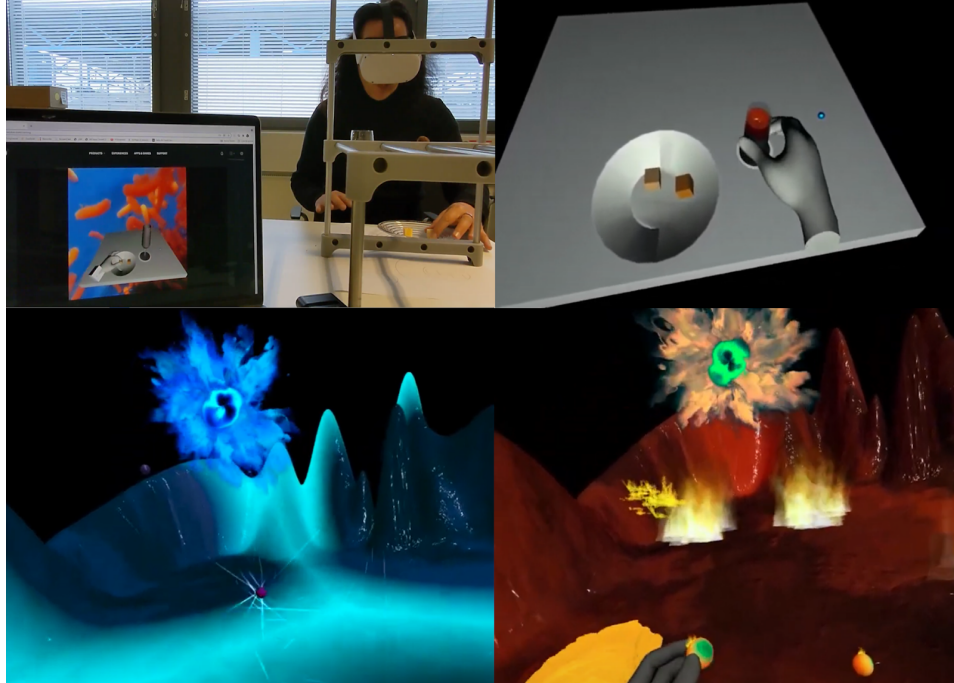


Figure 2. From left to right, top to bottom: (a) Setup, (b) Part A, (c) Part B cold planet environment, (d) Part B hot planet environment.

2.3 AESTHEMOS questionnaire on aesthetic emotions

In addition to investigating feelings of presence in mixed reality, in this study we were also interested in the aesthetic aspects of the multisensory eating experience, especially since our VR environments were designed as an art installation for a public art and science event. We investigated the emergence of aesthetic emotions [5], which can be elicited not only by stimuli that would be considered typical art works, but also for instance by design or natural landscapes.

Schindler and coworkers [38] developed a questionnaire for aesthetic emotions (AESTHEMOS) consisting of short expressions, applicable across different domains. Examples of items in the scale are: “I found it beautiful,” “Delighted me,” “Bored me” and “Challenged me intellectually”.

In another study [39] the authors identify 15 terms for emotions from clusters derived from a pool of 75 aesthetic emotion terms that were used to develop the AESTHEMOS questionnaire: Moved / In awe, Longing / Melancholic, Invigorated / Interested, Confused / Worried, Merry / Attracted, Fascinated / Enchanted, Intellectually Stimulated, Relaxed, Surprised, Sad, Pleased/feeling harmony, Displeased / Repelled, Delighted / Feeling beauty, Bored, Angry. A different classification is given by Schindler et al. [38], who group the AESTHEMOS questionnaire in four broad emotion subclasses: prototypical (feeling of beauty/liking, fascination, being moved, and awe), pleasant (joy, humor, vitality, energy, and relaxation), epistemic (surprise, interest,

intellectual challenge, and insight) and negative (feeling of ugliness, boredom, confusion, anger, uneasiness, and sadness).

The AESTHEMOS questionnaire has been used in research on emotions in the visual arts [40], film [41], music [42], architecture and nature [42]. A recent study [43] discusses the relevance of aesthetic emotions for gustatory and olfactory experiences, finding the AESTHEMOS well suited to determine the aesthetic emotions elicited by scents and tastes.

Based on the literature mentioned above, which demonstrates the wide applicability of this questionnaire, we decided to use it in the context of our experiment in mixed reality involving food, visuals and sound art.

2.4 Experimental procedure

The experiment was carried out during an art-science event at the Aistikattila multisensory laboratory, located at Flavoria in Turku University in Finland [44]. The Flavoria study protocol was reviewed and ethically approved by the Ethics Committee for Human Sciences at the University of Turku, Humanities and Social Sciences Division (37/2021). The study followed the European Union's General Data Protection Regulation (GDPR).

For Part A the questionnaire comprised:

- (i) Two food enjoyment questions where we asked participants to rate the affirmations “I enjoyed drinking the wine (eating the cheese)” with numeric 5-point scales. For these scales, the lowest value, 1, was interpreted as ‘completely disagree’, and the maximum, 5, as ‘strongly agree’. Responses were stored as two variables, ENJOYMENT WINE and ENJOYMENT CHEESE, and their average ENJOYMENT A.
- (ii) A list of the terms from the AESTHEMOS questionnaire, asking participants to check all the terms corresponding to their experienced emotions, that is, a Check-All-That-Applies (CATA) task. Responses were stored in dichotomous variables, one for each term, having the value of 1 if checked, 0 otherwise.

For Part B we formulated the same questions (i) on food enjoyment, related here to the chocolate and cheese balls (stored on the variables ENJOYMENT CHOCOLATE BALLS and ENJOYMENT CHEESE BALLS), and (ii) on aesthetic emotions, and moreover added the following items:

- (iii) The MPS scales with 10 questions about physical presence and self-presence (as we omitted the 5 questions regarding the "social presence" dimension, which were not relevant here because there was no social interaction). The answers were rated with a 5-points Likert scale from -2 to +2 and used to compute two variables, MPS_PHYS and MPS_SELF (see Section 3.2).
- (iv) Four congruence rating questions: congruence between the visual and the music environments and the chocolate and cheese balls (CONGRUENCE VISUAL (AUDIO) CHOCOLATE (CHEESE)) in 5-point scales from 1, “completely disagree” to 5, “strongly agree” that they are congruent. From the responses we computed two variables, CONGRUENCE VISUAL B and CONGRUENCE AUDIO B, averaging the visual and music ratings for each food, and a third variable CONGRUENCE B as their mean.
- (v) Four questions to evaluate the subjective temperature of the VR environment before and during eating the chocolate (TEMP_1_CHOCOLATE and TEMP_2_CHOCOLATE) and cheese balls (TEMP_1_CHEESE and TEMP_2_CHEESE), using 5-point scales from 1, “very cold” to 5, “very hot”. We computed two variables, TEMPERATURE CHOCOLATE and TEMPERATURE

CHEESE, as the mean of subjective temperatures before and during eating the chocolate and cheese balls, respectively, to represent the global temperature experience in each “planet”.

The experiment took, in total, about 15 minutes for each participant.

2.5 Data analysis

Data was analyzed with the free and open statistical software Jamovi 2.2.5. and with MATLAB R2017b.

3. Results and Discussion

3.1 Aesthetic emotions

We evaluated the aesthetic emotion profiles of Part A and B by the proportion of participants that ticked, for a given emotion cluster (see cluster description in Section 1.3. and S3), at least one AESTHEMOS term belonging to that cluster (Figure 3).

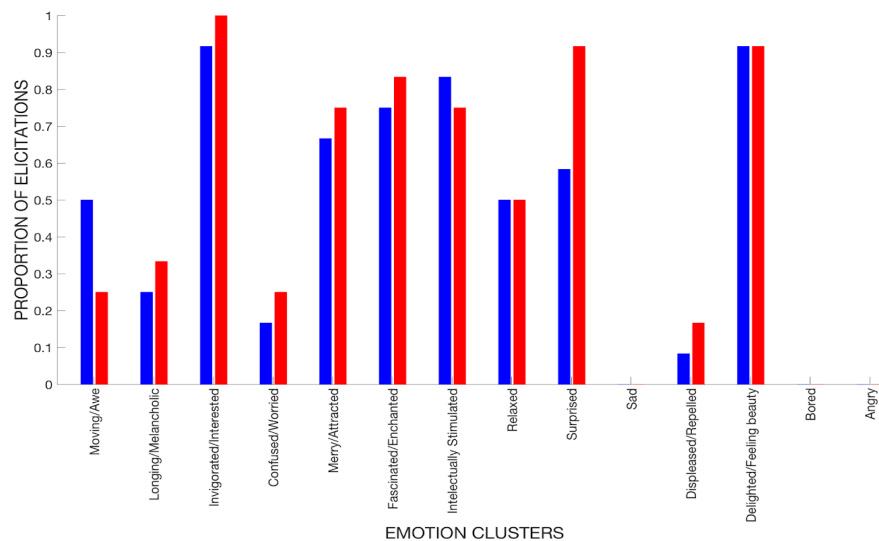


Figure 3. The aesthetic emotion profiles of the participants based on proportion for Part A (blue bars) and B (red bars) (1 representing that 100 % of the participants ticked an AESTHEMOS term from that cluster).

Only small differences in individual emotion clusters can be observed between parts A and B of the experience, although the atmospheres and food in both parts were quite different. Of the four broad subclasses of emotions considered in [38], the prototypical, pleasant and epistemic emotions were predominant in both parts of the experiment. The subclass of (so-called) negative aesthetic emotions (Confused/Worried, Displeased/Repelled, Sad, Bored and Angry) was scarcely represented, with no emotions selected in the last three negative categories. Somewhat similarly, in the study by Diessner and coworkers [43], less proportion of negative emotions of the AESTHEMOS were elicited by perfume and food items in comparison with a control

condition without chemical stimuli. In contrast to that study, however, epistemic emotions such as intellectual stimulation and surprise were also relevant in the present experiment, possibly reflecting the relative novelty of the experience and the fact that all the participants had just heard presentations on VR/MR dining and some of them were researchers in fields related to food science. Evaluating the CATA responses using the Cochran's Q test for each of the 11 emotion clusters having terms effectively selected within each part of the experiment (that is, excluding the Sad, Bored and Angry clusters), we found that the responses were significantly different within part A and B ($p < .001$). Note that for the Cochran's Q test it is required that the sample size is sufficiently "large"; as a rule of thumb, the number n of subjects for which the responses are not all 0's or 1's should be ≥ 4 and nk should be ≥ 24 , where k is the number of categories. These assumptions are met in our case.

Between parts, only Surprise A and Surprise B had a marginally significant difference ($t(11) = 2.16, p = 0.05$).

3.2 Presence

We evaluated presence using the multimodal presence scale regarding physical presence and self-presence.

Each item was rated from -2 to +2, and the two dimensions MPS_PHYS and MPS_SELF were computed as the sum of their respective 5 items; thus, they took values between -10 and +10.

The descriptive statistics show that both dimensions were positive (MPS_PHYS: $M = 2.33, SD = 3.75$; MPS_SELF: $M = 2.75, SD = 2.93$), indicating that the participants had a feeling of presence.

3.3 Food enjoyment, Congruence, Temperature

The enjoyment of the cheese and wine in Part A was high (ENJOYMENT CHEESE: $M = 4.17, SD = 1.337$; ENJOYMENT WINE: $M = 4.67, SD = 0.49$), and not significantly different between the food types ($t(11) = -1.15, p = 0.27$). In Part B also the enjoyment of the chocolate balls ((ENJOYMENT CHOCOLATE BALLS: $M = 4.33, SD = 0.98$) and cheese balls ((ENJOYMENT CHEESE BALLS: $M = 4.58, SD = 0.79$) was high and similar ($t(11) = -0.76, p = 0.46$).

Average food enjoyment was similar between parts A and B ($t(11) = -0.14, p = 0.88$).

Congruence between the chocolate balls and the VR environment was also high, both with respect to the visuals ($M = 4.08, SD = 0.79$) and music ($M = 4, SD = 0.6$). Similarly, congruence between the cheese balls and the VR environment was consistently high for the visuals ($M = 4.33, SD = 0.98$) and music ($M = 4.17, SD = 1.03$).

As mentioned in Section 2.3, in Part B we computed two variables, TEMPERATURE CHOCOLATE and TEMPERATURE CHEESE, as the mean of the subjective temperatures of chocolate and cheese balls, respectively. TEMPERATURE CHOCOLATE ($M = 2.75, SD = 0.62$) compared to TEMPERATURE CHEESE ($M = 3.75, SD = 0.5$) was significantly colder ($t(11) = -3.94, p = 0.002$), which was expected and consistent with the high congruence experienced between the food and the cold and hot planet environments.

3.4 Correlation structure between the variables in Part A

We considered the food enjoyment variable ENJOYMENT A (the average of ENJOYMENT WINE and ENJOYMENT CHEESE) and 11 aesthetic emotion variables, (MOVED/AWE A, LONGING/ MELANCHOLIC A, etc.), one for each of the 11 emotion clusters having at least one tick. These variables were defined as the proportion of checked AESTHEMOS terms belonging to the respective cluster, relative to the total number of terms in that cluster.

We found a positive correlation between food enjoyment and Fascinated / Enchanted emotions ($r = 0.626$, $p = 0.029$), and a negative correlation between food enjoyment and Confused/ Worried emotions ($r = -0.602$, $p = 0.039$) which became non-significant after Bonferroni correction; more importantly, the effect sizes are large [35].

We hypothesize that these correlations may show emotion transference [46-47], which refers to the carrying over of positive feelings about one stimulus (in this case, the VR environment) to positive feelings about a different one experienced at the same time (cheese and wine), this being reflected in the pleasure of eating and drinking [14]. By emotion transference, the fascination of an unusual virtual environment -an emotion reported by 75 % of participants- may have enhanced the delight of the food experience.

3.5 Correlation structure between the variables in Part B

We found a large effect size correlation ($r = 0.738$, $p=0.006$) between the self-presence (variable MPS_SELF) and the "moved / awe" cluster (see S3 for the Pearson correlation matrix of the response variables in Part B), which is consistent with a result shown in a study by Chirico and coworkers [48]: the feeling of presence and the "awe" emotion are bound. In our context, this can be interpreted as the fact that increased presence for place-based stimuli engender greater awe by increasing the perceived vastness and need for accommodation of the stimulus [49].

However, the congruence between food and environment (visual or auditory congruence or the mean congruence between the two modalities) was not significantly correlated with average food enjoyment, nor with enjoyment of cheese or chocolate specifically. In fact, there was no significant correlation between food enjoyment or food-environment congruence and any other variable, including all aesthetic emotions.

We also found a large effect size negative correlation between the perceived temperature of the chocolate balls and the cluster "relaxed" ($r = -0.718$, $p = 0.009$), which is difficult to interpret, since the emotional response was referred to the whole of Part B of the experience.

Finally, temperature of the "cold" environment before eating the chocolate balls (TEMP_1_CHOCOLATE) was correlated with temperature while eating them (TEMP_2_CHOCOLATE): $r = 0.618$, $p=0.028$, which suggests that the atmosphere anticipated the temperature during eating (at least in retrospective evaluation); with cheese (TEMP_1_CHEESE vs. TEMP_2_CHEESE) this did not happen ($r = 0.34$, $p = 0.27$).

In summary, we did not find evidence consistent with an impact of the VR "outer space" environment on the emotionality or enjoyment of food experience. However, food enjoyment was high even if its non-edible aspect and simulated movement were unfamiliar, which may have been enhanced by the presence of positive arousing emotions [50].

3.6. The case of Beauty

The applicability of the prototypical aesthetic emotion of beauty to food experiences has been an object of interest in philosophy and aesthetics at least since Aquinas.

Looking at responses to the first item of AESTHEMOS (“I found it beautiful”), we found that 8 out of 12 people (66%) found Part A beautiful, and 10 out of 12 people (83%) found Part B beautiful. As the response was related to the whole mixed reality experience, we cannot assess how this evaluation could be attributed more specifically to the food and/or VR environment components. We did not find a significant correlation between food enjoyment and the proportion of emotions selected from Delighted/Feeling Beauty cluster (see Section 3.4 and S2); however (see Section 3.4) we found in Part A of the experience large effect size correlations between food enjoyment and a different group of prototypical aesthetic emotions, the Fascinated/Enchanted cluster. A future study to resolve the emotional impact of these two factors (food and VR context) is warranted.

4. Conclusions

The use of the AESTHEMOS questionnaire in this study has shown that mixed reality food experiences can elicit a wide spectrum of aesthetic emotions, and in our case these emotions were mostly non-negative. In particular, feelings of beauty, that are an age-honored object of debate in the context of food, were experienced by most of the participants. Epistemic emotions such as intellectual interest and surprise were also prominent. Moreover, we found a positive correlation between food enjoyment and emotions of fascination and enchantment. The feeling of presence in the virtual environment was also correlated with the emotions of being moved/in awe. Food enjoyment was high in Part B of the experience, although its appearance was unusual, perhaps due to the playful interaction and positive arousing aesthetic emotions. In view of this, it could be interesting to explore the use of MR to, for example, alter the aspect of certain foods to make them more acceptable, overcome food neophobia and helping people to accept special diets by changing food aspect and environment.

With respect to gastrosonics in MR, one limitation of this study is that we did not evaluate the music by itself, either in its sensory or emotional dimensions. In previous research on the cognition of food in the presence of music, conducted in real environments, we and other investigators have found a decisive incidence of musical emotions on the overall emotionality of eating with music [51]. Also, crossmodal correspondences of music with taste affect the taste of food, an aspect we did not consider here. To investigate these aspects, we have designed a new VR environment where musical emotions and taste associations are expected to vary significantly, while the food is the same. This environment can be seen at [Barcelona Science & Cooking World Congress 2022 - Mixed Reality Food Experi...](#)

Finally, we hope that our approach to composing MR food experiences and examining them with tools elaborated for aesthetic studies could inspire artists and designers to conceptualize these novel eating experiences as a potential field for multisensory art.

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