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Comparison between discrete and continuous analysis of facial expressions, elicited by bitter-tasting beverages in overweight and healthy-weight individuals

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Abstract

The aim of the present study was to compare the information provided by a discrete and continuous data analysis of two emotions (disgust and joy), elicited by bitter-tasting beverages (coffee, yerba mate infusion and grapefruit juice) in two groups with different Body Mass Index (BMI): overweight group (25 < BMI < 30), and healthy-weight control group (18.5 < BMI ≤ 25). Participants (n = 66; 34 females, 32 males) evaluated a total of three consecutive sips of the same beverage (taking one sip every 20 seconds (s) and registering a continuous video for 60s. The Wilcoxon test (continuous analysis) showed some changes generated as the drinks were being consumed. The biggest difference was the expression of disgust for coffee in the high BMI group, at the first sip (0-10s). It represented 27% compared to 2% in normal BMI. The continuous analysis allowed to observe the periods where the differences were greater (0-10 and 40-50s).

Keywords: continuous analysis; discrete analysis; facial expressions; bitter taste; overweight; BMI

1. Introduction

The experience of eating and drinking is a complex and multifaceted process that elicits affective patterns across time; in general, appetitive and pleasant responses to sweet items occur, while aversive and unpleasant responses result when tasting bitter substances. Indeed, it has been used to assess that the acceptance of foods is largely based on these affective patterns (Drewnoski, 1997)

In prior research of food acceptance and preferences, multiple affective measures have been selected from explicit emotional responses (e.g., hedonic self-reports) to more implicit responses (e.g., automatic and psychophysiological patterns). As findings suggest that people's food choice depends more on mechanisms that are independent of higher order cognitive assessments (Scarabis *et al.,* 2006). Among such measures, facial reactions are highly valued as a primary behavioral index of affective experience as well as the richest source of non-verbal information associated with emotion (Ekman *et al.,* 2002; Ekman *et al.,* 2005). Applied to eating and drinking experiences, facial expressions have been highlighted for their lower sensitivity to the effects of social desirability and greater accuracy in the exploration of taste perception, isolated from the motivational properties of the taste (Berreidge *et al.,* 2000).

Recent progress in computer vision and computational algorithms has made it possible to analyse the facial expressions based on the tracking of subtle changes in facial features on a moment-by-moment basis. Indeed, automated facial coding platforms have been developed to assess emotions using the Facial Action Coding System (FACS), including the Noldus' FaceReader and iMotions' Facet platforms (Dupré *et al.,* 2019). The FACS refers to a set of facial muscle movements that correspond to a displayed emotion (Ekman et al., 2005).

Alvarez-Pato et al. (2020) showed that Facial Emotion Recognition (FER) alone was not enough to determine consumers' acceptance. FER by itself is not a problem with a single straightforward solution; still, many variables must be considered. However, Bredie et al. (2014) and Crist et al. (2018) were successful in evoking expressions of disgust with highly concentrated solutions of caffeine, citric acid, and sodium chloride. García Burgos and Zamora (2013; 2015) also found disgust reactions with bitter chocolate and coffee.

Previous studies of automatic facial expression analysis with computer-based systems (de Wijk *et al.,* 2012; Danner *et al.,* 2014; Garcia-Burgo *et al.,* 2013, 2015; Rocha –Parra *et al.,* 2016; Gunaratne *et al.,* 2019; van Bommel, *et al.,* 2020) have reported results using single integrated values, such as the intensity average of the emotion over time. They used a discrete analysis of the emotions evaluating the data at fixed points in time of the dynamic registers. However, when the consumer interacts with a food during the consumption experience, a series of physical (e.g., chemical reactions), physiological (e.g., molecule-taste receptor interactions) and psychological (e.g., flavor perception) phenomena change over time (Delarue *et al.,* 2015; Dijksterhuis *et al.,* 2001; Galmarini *et al.,* 2015; Sudre *et al.,* 2012). Consequently, does dynamic data analyses of the changes over time seem to be more adapted than simple measures that integrate and summarize all these events in a single value?

In this case, Crist *et al.* (2016) used the time variable as a determining factor to analyze the behavior of facial expressions. This work was the first to propose a standard data analysis methodology, where time series are used to extract each participant`s treatment response to a control stimulus as baseline. The emotional time series analysis was able to detect emotional changes and statistical differences between the control (unflavored water) and respective treatment. Walsh *et al.* (2017) used the time series for comparison of the seven emotions expressed between the three sets of control videos and emotion eliciting videos. The authors also evaluated by ANOVA the mean intensities of emotions, expressed over five seconds (prior and post event video). No significant differences in expressed emotional intensity were found, while time series statistical analysis results were valuable in evaluating the dynamic nature of the emotional responses. Thus, while discrete analysis focuses on certain time periods, the continuous data objects generate a stream of values which can be of indefinite in length. Finally, other example of continuous analysis is provided by Mahieu *et al.* (2019) who made an evaluation called a "*temporal approach"* where the mean emotion score was computed for each product evaluated and each emotion over the panel at each time (every 1/6 s). The temporal analysis was done through a bilateral t-test (α=5%) that compared the mean (intensity of reaction) of a given product with respect to its zero value.

Consequently, the present work used a continuous analysis of facial expressions elicited by bitter foods to test the potential relationship between the rejection of less palatable healthy bitter food and overweight. Facial expressions are more suitable to measure dislikes than likes because negative facial expressions are quicker to appear and less influenced by other factors compared to positive facial expressions (van Bommel et al., 2020). Moreover, we compared the affective reactions of healthy-weight with overweight groups to bitter beverages using a discrete versus continuous analysis. If being overweight has any connection with the rejection of bitter-tasting foods, it would be expected a decreased the liking of the beverages, especially in high BMI condition. The liking data of the present work were previously published in León Bianchi et al. (2018). To date no previous studies have specifically investigated such aversive reaction-weight gain association or compared discrete and continuous analysis related to bitter-tasting foods.

2. Materials and Methods

2.1. Participants

In total, 66 healthy adults from the Pontificia Universidad Católica Argentina (UCA; 34 females, 32 males; 18 to 61 years old) participated in the study. This number of participants (N=66) was selected from an initial sample of 80 participants, after the removal of videos with mistakes.They were asked to report their height and weight. Finally, two groups were formed based on the calculated body mass index (BMI): normal BMI (n = 34; 18 females, 16 males), consisting of subjects with 18.5 < BMI < 25 (mean BMI = 21.2 (SD= 1.2); mean age = 28.0 (SD= 6.5)); and high BMI (n = 32; 15 females, 17 males), encompassing participants that were within the overweight range, 25<BMI < 30 (mean BMI 29.0 (SD= 2.3); mean age= 38.0 (SD= 8.3)). The BMI ranges corresponded to the World Health Organization classification according to the nutritional status of adults (OMS, 2003). Exclusion criteria included bitter food aversions, smoking (more than 5 cigarettes per week (Sato *et al.,* 2002)) illnesses, a history of eating disorders, diabetes and allergy to the products to be tested in the study. Also, people who described themselves as being on weight-loss diets or actively losing weight were excluded since this might lead to bias when reporting sensory and affective perceptions of stimuli (Tepper *et al.,* 2002)

2.2. Beverages

Three beverages were selected based on their different bitter compounds and bitter intensity: coffee (*La Virginia*, Argentina), *yerba mate* infusion (*La Tranquera*, Argentina) and grapefruit juice (*Citric*, Argentina). Nutritional data was obtained from the product packaging (pH, protein, carbohydrate, caffeine; Leon Bianchi et al., 2018) .

The main bitter compounds of these beverages are caffeine (for coffee), caffeine, theobromine, and theophylline (for yerba mate) and naringin (for grapefruit). Yerba mate (*Ilex paraguariensis*) is a native plant from South America consumed as an infusion because of its stimulating and energizing characteristics (Orjuela Palacio et al., 2014)

The coffee and *yerba mate* infusions were prepared the day of the tasting as follows: coffee (three sachets, 7 g each) and yerba mate (two sachets, 3 g each) were put in 200 mL of mineral water at 90 ± 2 ºC for 5 minutes. Both infusions were tasted at 45 ± 2 ºC. Grapefruit juice was stored at 4 ºC and served directly from the original packaging at 20 ± 2 ºC. Each beverage was evaluated at the usual consumption drinking temperature. The levels of bitter intensity were measured by a trained panel (10 panelists) of Universidad Católica Argentina, using a non-structured scale of 15 cm from 1 (non-bitter) to 15 (very strong-bitter), according to a previous experiment (Leon Bianchi et al., 2018). Bitter intensity of beverages was: 11.2, 8.1 and 2.7 for coffee, yerba mate and grapefruit juice, respectively. These intensities were different at $p \leq .05$.

2.3. Evaluation procedure

The participants (66) evaluated the affective value of coffee, *yerba mate* infusion and grapefruit juice by the Time-Intensity (T-I) method for liking as it was described in León Bianchi *et al.* (2018), responding to the question: How do you like this beverage now?

During the T-I evaluation each participant took a total of three consecutive sips of the same beverage (10mL/sip), served in separate cups, taking one sip every 20 seconds (s), and registering a continuous rating for 60 s. The participants were first instructed to look towards the camera until the experimenter indicated that the 10 seconds of neutral recording was up. Afterward, the participants received the second instruction giving their liking using the Time-Intensity methodology: "You will receive three cups of a same sample and you will evaluate the liking through a 60 s period responding to the question: How do you like this beverage now? For that you will put the entire content of the first cup of the sample in your mouth, and at the same time press the start button and evaluate the level of liking using the mouse to move the cursor along the line scale on the screen. When the timer indicates 20 s, put the content of the second cup of the sample in your mouth and continue the evaluation. At 40 s, put the content of the third cup of the beverage in your mouth and continue the evaluation of liking until 60s"

The participants did not rinse their mouths between sips. The timing of sample sips was managed by a timer on the screen; in this way, time was standardized *a priori* for the panel. A preliminary test was made to design the timing between sips (Rocha-Parra *et al.,* 2016).

Beverages were served in transparent plastic containers and the order of presentation was balanced among the participants. The subjects evaluated the three beverages in the same session. They had a 10-minute break between each beverage for resting and rinsing their mouth with mineral water. The experiment was conducted in an individual booth (at 22 ± 2º C) equipped with a computer for data acquisition. The affective value of drinks was measured by the parameters of Time-Intensity curves: maximum intensity and area under the curve.

2.3.1. Facial expressions of basic emotions

The affective parameters were provided by the analysis of the facial patterns following the procedure of García-Burgos *et al.* (2013), Facial reactions were videotaped with a digital video camera (JVC GZ-MS150SU), which was located directly above the computer screen and in front of the subject at 1.5 m. The illumination of the participant's face was optimized by using daylight lamps (6500 k) in addition to the ceiling lights. The cups used were transparent so that they did not interfere with the recording. In addition, the camera had face detection technology which identified people's faces following their movements and adjusted achieve the optimum focus, exposure and white balance. The experimenter followed the facial expressions in real time watching the camera screen without being seen by the subjects. The video files were run through the FACET™ SDK (iMotions Inc., Cambridge Innovation Center, US). The automatic facial expression recognition software tracked and analyzed frame-by-frame (25 frames per second) the intensity (as estimated by expert human coders from 0 [=absent] to 1 [=very high intensity]) of disgust and joy emotions as a measure of flavor unpleasantness and pleasantness, respectively. Based on the Facial Action Coding System (FACS) developed by Ekman & Friesen (1978), several software's were derived. FACS discriminates facial movements characterized by action units (AUs) on a 5-point intensity scale. This approach requires trained review experts, manual coding, significant evaluation time, and provides limited data analysis options (Crist et al., 2016). Detailed information on how facial expressions are identified with iMotions™ is described in the Facial Expression Analysis by Krosschell (https://imotions.com/blog/facial-expression-analysis/).

The Protocol for facial expression video recording and the Informed consent were approved by the Ethics Committee of the Pontificia Universidad Católica Argentina

2.4. Data estimation and data analysis

Sample size calculation was based on exploring the relationship between BMI (2 groups) and the perception and hedonic response to bitter beverages (3 measurements) using the software G*Power (version 3.13; Cardenas Castro et al., 2014). Assuming two-sided tests with $\alpha= 0.05$, $\beta = 0.05$, and effect size $f = 0.50$, the required sample size would be 66 to ensure a power >0.95, $F[2, 128] = 3.067$.

After excluding frames without facial tracking due to head movements (e.g., shaking and turning the head, head-down motions) and occlusions of the face (e.g., when hand gestures occluded parts of the face); approximately 80% of the video frames were analyzable by the software. The initial sample of participants was higher than 66 to consider the mistake in the video registers. Ten seconds before the first sip were used as a baseline for all the analysis.

The software used delivers a temporary database of intensities (25 Hz, 25 frames per second). Information was manually extracted in the seconds chosen in order to make the discrete analysis, which corresponded the average of these 25 scores at between 1 and 2 seconds (first sip), 5 and 6 seconds (second sip) and 10 and 11 seconds (third sip). Then, they were transformed into mean values. In this way, a total of 9 events (3 seconds x 3 sips) were integrated into 9 mean values obtained from the frame-by-frame analysis (9 x 25 =225 frames in total) of the automatic facial expression recognition software data base.

Regarding the continuous analysis of the emotions, the protocol described by Crist et al. (2016), was carried out to evaluate in a continuous way how the emotional response varies over time after drinking each of the three beverages. In the continuous analysis all the frames generated during the 60 seconds of the test were evaluated (25 frames per second) (60 x 25 =

1500 frames). This methodology graphically shows the evolution of the facial reaction intensity and its directionality in a specific time frame. The overall emotional response over time and across multiple participants can be quantified by time pairing each participant's treatment response to a control stimulus (baseline); in that work Crist et al. (2016) used water as a baseline. The results of Wilcoxon test (continuous analysis) were showed as time percentage (%), where the intensities of emotions between the drinks (coffee vs juice or mate vs juice) presented significant differences. In the graphs, the dotted lines (which represent the time periods with significant difference between drinks) show above the timeline the greater differences for coffee or mate, and below the timeline the greater differences for juice. The percentages underlined correspond at the 60 seconds of the entire test. To compare the results obtained from discrete analysis to continuous, differences in facial reactions (disgust and joy) for each separate BMI (normal and high) were made by comparing coffee to juice and mate to juice using 2 Drink X 3 Sip X 3 Time mixed-factorial ANOVAs. The level of significance established was $p \leq .05$.

Grapefruit juice was selected as a baseline to apply the Wilcoxon test.

3. Results

3.1. Discrete analysis of emotions

The average intensities of disgust and joy in the facial expressions elicited by drinking three consecutive sips of the three different bitter beverages in the high and normal BMI consumer groups are shown in Figure 1. Each sip was evaluated at 1-, 5-, and 10 seconds. In general, the results showed a more intense reaction of disgust than joy in all three drinks. The mean intensities (± SEM) of disgust for the high BMI were 0.068 ± 0.003, 0.066 ± 0.004, and 0.045 ± 0.002 (for coffee, mate, and juice, respectively); while for joy they were 0.036 ± 0.003, 0.031 ± 0.003 and 0.050 ± 0.005 (for coffee, mate and juice, respectively), (Fig 1 a, b). In normal BMI, the intensities of disgust were 0.060 ± 0.003, 0.101 ± 0.004 and 0.069 ± 0.002 (for coffee, mate and juice, respectively) and, for joy they were 0.041 ± 0.003, 0.041 ± 0.003 and 0.040 ± 0.003. (for coffee, mate, and juice, respectively), (Fig. 1 c, d). Coffee and mate showed a greater disgust reaction in the high BMI group compared to juice, while the expression of joy was greater for juice. For the normal BMI group, none of the three drinks showed significant changes in disgust reaction over time. The mate infusion showed the highest intensity of disgust (0.101 ± 0.004). In the case of the joy reaction, the normal BMI group showed no differences between the drinks and decreased in the period from 5- to 10- s.

Figure 1

3.2. Continuous analysis of emotions

Figure 2 shows the time series analysis focused on the disgust and joy facial expression, comparing coffee and mate versus juice (baseline) in high BMI group. The presence of the dotted line above the time axis indicates that disgust or joy facial reaction generated by coffee or mate is significantly different and higher than that generated by juice ($p<.05$). Likewise, a dotted line below the time axis indicates that the expression of disgust or joy provoked by juice is statistically greater than that generated by coffee or mate ($p<.05$).

In this group (high BMI) is seen that the biggest differences in disgust reaction for coffee were observed at the intervals 0 –10; 40 – 50 sec (27 % and 13 % respectively). The average of disgust (coffee > juice) after drinking the three sips was 12% (Figure 2a) Regarding the mate drink, high BMI group showed a smaller difference in the disgust reaction with respect to the juice (7%) and the periods of greatest difference were the intervals 0 –10; 40 – 50 sec (11 % and 10 % respectively) (Figure 2b)

In high BMI group the average expression of joy elicited by grapefruit juice was higher when compared to mate than when compared to coffee (11 % and 4%, respectively) ($p<0.05$). In the case of mate, the joy reaction generated by the juice was greater in the periods at the intervals 30 –40; 40 – 50 sec (20 and 23 %, respectively) (Figure 2d)

Figure 3 shows the time series analysis focused on the disgust and joy facial expression, comparing coffee and mate versus juice (baseline) in normal BMI group.

Regarding the reaction of disgust in this group (normal BMI) the biggest differences were obtained in the mate. The average of disgust (mate > juice) after drinking the three sips was 8% and the periods of greatest difference were the intervals 0 –10; 20 – 30 sec (14 % and 19 % respectively) (Figure 3b).

Considering the differences observed in joy reaction in the normal BMI group this expression was always higher in juice when compared to mate or coffee. The average of joy (juice > mate) was 17%. This same average but this time with respect to coffee (juice > coffee) was lower (12%). In both cases, the normal BMI group showed a greater reaction of joy in the first 30 seconds

Figure 2 and 3 here

3.3. Comparison between discrete and continuous analysis

As the Wilcoxon test (continuous) evaluated the statistical difference of coffee or mate against juice (baseline) for discrete analysis was made an ANOVA test to evaluate this difference

(Table 1). Table 1 shows the differences of the main factors (Drink, Sip and Time) and its interactions within each BMI group (normal and high). For disgust expression, high BMI showed a higher effect from coffee vs. juice ($p < .01$) and mate vs. juice ($p < .05$). For joy expression, the only difference was observed when comparing mate vs. juice ($p < .05$). No other effects or interactions were significant. In the case of normal BMI, the analysis showed a higher disgust expression of mate vs. juice ($p < .001$). A decrease of joy expression was observed over time in coffee vs juice ($p < .001$) and, an interaction Drink x Sip in mate vs. juice ($p < .05$).

Table 1 here.

4. Discussion

The main hypothesis of the current study was, that continuous analysis of facial expressions elicited by bitter foods seem to be a more valid and accurate tool than discrete analysis in order to capture the multiple aspects of consumption experience. The obesity of the population is related to affective mechanisms that control dietary selection and food consumption, which are dynamic processes. Interestingly, León Bianchi *et al*. (2018) found that the high BMI group rated the bitter taste as less intense, but they had a lower level of acceptance than normal BMI. This result suggests that the hedonic rather than the sensory component might be playing a crucial role in the perception of bitter taste in individuals with high BMI.

Two modalities of data analysis, discrete and continuous, were applied to the results of the facial expressions in two groups of people (healthy-weight and overweight people) after drinking bitter beverages.

Both methodologies of data analysis (discrete and continuous), showed that there was a greater presence of disgust reaction when the high BMI group drank coffee compared to the normal BMI. However, only the continuous analysis allowed to observe the periods where the differences were greater, mainly in the first and last sip (0-10 and 40-50 seconds, respectively). For example, the normal BMI group presented in some periods (38-50 s), a greater presence of disgust after drying juice compared to coffee, an increase of joy (40-s) the coffee vs. juice. These differences could explain the greatest disgust of mate compared to juice, in the same group. Does the aroma of coffee have any influence on the emotions of the normal BMI group, and only bitter taste could affect the emotions of the high BMI group? Future studies must be performed to confirm these questions.

By continuous analysis it can be seen over time that joy was less present than disgust (4% and 12% respectively; Figure 2 a, b). Different studies of facial expressions have found the same behavior, where negative facial reactions were significantly more intense than positive ones

(Horio *et al.,* 2003; Weiland et al., 2010; de Wijk *et al.,* 2012; Danner *et al.,* 2014; Kostyra *et al.,* 2016; Rocha-Parra *et al.,* 2016; Le Goff *et al.,* 2017).

He et al. (2015) studied the temporal dynamics of emotional facial expressions to pleasant and unpleasant food odors. Some facial expressions such as disgust and sad reached their maximum intensity relatively early (roughly between 1000 and 1500 ms after stimulation), and others such as angry, sad and happy reached their maximum relatively late (roughly between 3000 and 3500 ms after stimulation). In general, fish odor caused more intense facial expressions than orange odor, irrespective whether they refer to positive (e.g., happy, surprised) or negative (e.g., disgust, sad) emotions.

In the present work with continuous analysis it was possible to observe a more heterogeneous distribution in the changes of facial expressions generated by the beverages evaluated across the entire period of the event (60 seconds). Although in general, the greatest differences are shown in the first sip (0-10 sec; Figures 2 and 3), this is not maintained along the other two sips (absence of the dotted line). In some cases, the difference is only in a certain period (40-50 sec) (Figure 2 d).

The two methods showed the greater presence of the disgust reaction in the group of the high BMI after drinking coffee, which is the more bitter drink. In the case of continuous analysis, the difference was detected throughout the entire period, regardless of the BMI. The greater presence of the disgust reaction in the high BMI in the case of Wilcoxon could be explained by the almost null presence of the emotion of joy for that same population group (see Figure 2 b).

Both methodologies (discrete and continuous) showed that for two different drinks (coffee and mate), there is no defined pattern with respect to BMI. Regarding coffee, there is a greater expression of disgust in the high BMI group, and in the case of mate this behavior is reversed being the normal BMI who presents greater expression of disgust. These results agree with the other works on the subject, which emphasize how difficulty to associate anthropometric measures such as BMI with the bitterness of certain foods. People characteristics, such as age, gender, genetics and ethnicity seem to play a role in bitterness perception. Therefore, data about associations between bitterness perception and anthropometrics can be conflicting (Choi *et al.,* 2000; Simchen *et al.,* 2000; Leon Bianchi *et al.,* 2018; Shizukuda *et al.,* 2018).

Visalli et al. (2020) discussed several aspects of sensory temporal data collection, their benefits and defects, and some questions about the level of detail to look at in temporal data. When comparing the results of two methods, they observed that both methods discriminated the products in a very similar way. This suggests that considering temporality in only 3 periods could be the right level of precision which can be expected of temporal data collected with consumers, at least for this type of products. These conclusions can be associated with the present work.

Both methodologies of data analysis (discrete and continuous) showed similar discrimination levels. Continuous analysis provided a more detailed information distributed over time.

Hill (2008) pointed out that facial expressions have a rapid time sequence: an onset, a peak and a fade wherein the duration of expression will generally range from half a second to four seconds. Arnade (2014) used facial recognition to continuously analyse the emotional response (happy, surprised, angry, sad, scared, and disgusted) to a dairy stimulus for three analysis time durations (5, 10, 20s). These results suggested that the time durations investigated could have been too long to obtain truthful descriptive depictions and may dilute accuracy in response. Furthermore, it suggested that a longer time duration wouldn't necessarily provide valuable information and may continue to increase neutral response and dilute actual basic emotion response

Some limitations of the present work should be considered in order to provide more accurate information. Several results of continuous analysis can be difficult to interpret, for example, the greater presence of disgust reaction after drinking juice compared to coffee. Crist *et al.* (2016, 2018) used this methodology using water as a baseline, and in the present work juice was used as a baseline. It is necessary to consider other beverages with a bitter taste to observe greater differences over time. A prolonged baseline without any flavor could have negative effects for the subject increasing the boring (Mahieu et al., 2019), and so the disgust facial reactions. Different approaches to data analysis (such as a binomial test) and result presentations could be assayed, like the curves used in Temporal Check-All-That-Apply (Castura et al., 2016).

5. Conclusion

Discrete versus continuous analysis of facial expressions to bitter taste reactivity in overweight and normal-weight individuals showed the greatest presence of disgust in the high BMI after drinking coffee compared to the normal BMI. The continuous analysis method allows a greater amount of information that could be lost when using discrete analysis. The continuous analysis showed graphically those constant changes that are generated as the drinks are being consumed. Although in general, the greatest differences are shown in the first sip during the first 10 seconds, in some cases, that difference was best detected in other periods of time. The continuous analysis allowed to observe the periods where the differences were greater (0-10 and 40-50s).

Conflicts of Interest: none

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References

Álvarez-Pato, V.M., Sánchez, C.N., Domínguez-Soberanes, J., Méndoza-Pérez, D.E., & Velázquez, R. (2020). A Multisensor Data Fusion Approach for Predicting Consumer Acceptance of Food Products. *Foods*, **9**, 774.

Arnade, E. A. (2014). Measuring Consumer Emotional Response to Tastes and Foods through Facial Expression Analysis . *Thesis Virginia Tech,* (2014-01-15).

Berridge, K. C. (2000). Measuring hedonic impact in animals and infants: Microstructure of affective taste reactivity patterns. *Neuroscience and Biobehavioral Reviews,* **24**(2), 173–198.

Bredie, W.L., Tan, H.S.G., & Wendin, K. (2014). A comparative study on facially expressed emotions in response to basic tastes. *Chemosens. Percept.,* **7**, 1–9.

Cárdenas, M., & Arancibia, H. (2014). Potencia estadística y cálculo del tamaño del efecto en G*Power: Complementos a las pruebas de significación estadística y su aplicación en psicología. *Salud & Sociedad,* **V5.N2,** 210-224.

Castura, J. C., Antúnez, L., Giménez, A., & Ares, G. (2016). Temporal Check-All-That-Apply (TCATA): A novel dynamic method for characterizing products. *Food Quality and Preference,* **47,** 79–90

Choi, S. E., & Chan, J. (2015). Relationship of 6-n-propylthiouracil taste intensity and chili pepper) use with body mass index, energy intake, and fat intake within an ethnically diverse population. *Journal of the Academy of Nutrition and Dietetics,* **115**(3), 389–396.

Crist, C. A., Duncan, S. E., & Gallagher, D. L. (2016). Protocol for Data Collection and Analysis Applied to Automated Facial Expression Analysis Technology and Temporal Analysis for Sensory Evaluation. *Journal of Visualized Experiments,* **114**, 1–15.

From the publication of Crist et al. (2016) we follow the methodological scheme in the treatment of some data presented in this manuscript

Crist, C. A., Duncan, S. E., Arnade, E. A., Leitch, K. A., O'Keefe, S. F., & Gallagher, D. L. (2018). Automated facial expression analysis for emotional responsivity using an aqueous bitter model. *Food Quality and Preference*, **68**, 349–359.

The work of Crist et al. (2018) allows us to see that the analysis of time series used in the present research is a promising tool for interpreting the emotional results and is more sensitive to emotional changes than mean comparisons

Danner, L., Sidorkina, L., Joechl, M., & Duerrschmid, K. (2014). Make a face! Implicit and explicit measurement of facial expressions elicited by orange juices using face reading technology. *Food Quality and Preference,* **32,** 167–172.

de Wijk, R. A., Kooijman, V., Verhoeven, R. H. G., Holthuysen, N. T. E., & de Graaf, C. (2012). Autonomic nervous system responses on and facial expressions to the sight, smell, and taste of liked and disliked foods. *Food Quality and Preference,* **26**(2), 196–203.

Delarue, J., & Blumenthal, D. (2015). Temporal aspects of consumer preferences. *Current Opinion in Food Science,* **3**, 41–46.

Dijksterhuis, G. B., & Piggott, J. R. (2001). Dynamic methods of sensory analysis. *Trends in Food Science and Technology*, **11,** 284–290.

Drewnoski, A. (1997). Taste preferences and food intake. *Nutrition,* **17**, 237–256.

Dupré, D., Krumhuber, E., Küster, D., & McKeown G.J. (2019). Emotion recognition in humans and machine using posed and spontaneous facial expression. *PsyArXiv*, 26 Sept. https://doi.org/10.31234/osf.io/kzhds

Ekman, P., & Rosenberg, E. (2005). What the Face Reveals: Basic and Applied Studies of Spontaneous Expression Using the Facial Action Coding System (FACS) (2nd ed.) *New York: Oxford University Press.*

Ekman, P., Friesen, W. V., & Hager, J.C. (2002). Facial Action Coding System. Manual and Investigator's Guide. Salt Lake City, UT: *Research Nexus.*

Ekman, P., & Friesen, W. V. (1978). Facial action coding system: A technique for measurement of facial movement. Palo Alto, CA: *Consulting Psychologists Press.*

Galmarini, M. V., Symoneaux, R., Visalli, M., Zamora, M. C., & Schlich, P. (2015). Static vs. dynamic liking in chewing gum: A new approach using a background task and a natural setting. *Food Quality and Preference,* **40**, 381–386.

Garcia-Burgos, D., & Zamora, M. C. (2013). Facial affective reactions to bitter-tasting foods and body mass index in adults. *Appetite,* **71,** 178–186.

Garcia-Burgos, D., & Zamora, M. C. (2015). Exploring the hedonic and incentive properties in preferences for bitter foods via self-reports, facial expressions and instrumental behaviours. *Food Quality and Preference,* **39,** 73–81.

Gunaratne, T.M., Fuentes, S., Gunaratne, N.M., Torrico, D.D., Gonzalez Viejo, C., & Dunshea, F.R. (2019). Physiological Responses to Basic Tastes for Sensory Evaluation of Chocolate Using Biometric Techniques. *Foods,* **8**, 243.

He, W., Boesveldt, S., de Graaf, C., & de Wijk, R.A. (2016). The relation between continuous and discrete emotional responses to food odors with facial expressions and non-verbal reports. *Food Q. Prefer,* **48**, 130-137

Hill, D. (2008). *Emotionomics: Leveraging Emotions for Business Success*. London; Philadelphia: Kogan Page.

Horio, T. (2003). EMG activities of facial and chewing muscles of human adults in response to taste stimuli. *Perceptual and Motor Skills,* **97**(1), 289–298.

Kostyra, E., Blicharski, T., & Po, E. (2016). Consumer facial expression in relation to smoked ham with the use of face reading technology. The methodological aspects and informative value of research results. *Meat Sci.,***119,** 22–31.

Krosschell, K. (2020). Facial Expression Analysis: The Complete Pocket Guide. https://imotions.com/blog/facial-expression-analysis/.

Le Goff, G., & Delarue, J. (2017). Non-verbal evaluation of acceptance of insect-based products using a simple and holistic analysis of facial expressions. *Food Quality and Preference,* **56,** 285–293.

León Bianchi, L., Galmarini, M. V., García-Burgos, D., & Zamora, M. C. (2018). Time-intensity and reaction-time methodology applied to the dynamic perception and liking of bitterness in relation to body mass index. *Food Research International,* **109** (April), 606–613.

This publication is the first part of the present work, the data of Leon Bianchi et al (2018) help to discuss some results found in this research.

Mahieu, B., Visalli, M., Schlich, P., & Thomas, A. (2019). Eating chocolate, smelling perfume or watching video advertisement: Does it make any di ff erence on emotional states measured at home using facial expressions? *Food Quality and Preference,* **77**(May), 102–108.

OMS (2003). Dieta, nutrición y prevención de enfermedades crónicas. Serie de Informes Técnicos. *vol. 916*. Ginebra.

Orjuela-Palacio, J.M., Zamora, M.C., & Lanari, M.C. (2014). Consumers' acceptance of a high-polyphenol yerba mate/black currant beverage: effect of repeated tasting. *Food Res Int,* **57**,26–33.

Rocha-Parra, D., García-Burgos, D., Munsch, S., Chirife, J., & Zamora, M. C. (2016). Application of hedonic dynamics using multiple-sip temporal-liking and facial expression for evaluation of a new beverage. *Food Quality and Preference,* **52,** 153–159.

Sato, K., Endo, S., & Tomita, H. (2015). Sensitivity of Three Loci on the Tongue and Soft Palate to Four Basic Tastes in Smokers and Non- smokers. *Acta Oto- Laryngologica,* **122:4,** 74-82

Scarabis, M., Florack, A., & Gosejohann, S.K. (2006). When consumers follow their feelings: The impact of affective or cognitive focus on the basis of consumers' choice. *Psychology and Marketing,* **23:12**, 1015–1034.

Shizukuda, S., Marchini, J. S., Adell, A., Santos, M. A., Fernanda, C., Brandao, C., Maria, C., Lima, M., Freire, S., Cunha, C., Itikawa, E. N., & Silvah, J. H. (2018). Nutrire Influences of weight , age , gender , genetics , diseases , and ethnicity on bitterness perception : a narrative review of current methodological aspects*. Nutrire,* **43,** 1–9.

Simchen, U., Koebnick, C., Hoyer, S., Issanchou, S., & Zunft, H. (2006). Odour and taste sensitivity is associated with body weight and extent of misreporting of body weight. *Eur. J. Clin. Nutr,* **60,** 698–705.

Sudre, J., Pineau, N., Loret, C., & Martin, N. (2012). Comparison of methods to monitor liking of food during consumption. *Food Quality and Preference,* **24**(1), 179–189.

Tepper, B. J., & Ullrich, N. V. (2002). Influence of genetic taste sensitivity to 6-n-propylthiouracil (PROP), dietary restraint and disinhibition on body mass index in middle-aged women. *Physiol. Behav.*, **75**, 305–312.

van Bommel, R., Stieger, M., Visalli, M., de Wijk, R., & Jager, G. (2020). Does the face show what the mind tells? A comparison between dynamic emotions obtained from facial expressions and Temporal Dominance of Emotions (TDE). *Food Quality and Preference,* **85**, 103976.

Visalli, M., Mahieu, B., Thomas, A., & Schlich, P. (2020). Concurrent vs. retrospective temporal data collection: Attack-evolution-finish as a simplification of temporal dominance of sensations? *Food Quality and Preference* In Press.

The conclusions of Visalli's work et al (2020) can be associated with the present work. The discussion of several aspects of sensory temporal data collection, supports the discussion of the present research.

Walsh, A. M., Duncan, S. E., Bell, M. A., O'Keefe, S. F., & Gallagher, D. L. (2017). Integrating implicit and explicit emotional assessment of food quality and safety concerns. *Food Quality and Preference,* **56**, 212–224.

Weiland, R., Ellgring, H., & Macht, M. (2010). Gustofacial and olfactofacial responses in human adults. *Chemical Senses,* **35**(9), 841–853.

Table 1. ANOVA F-values of disgust and joy emotional responses from beverages

Factors and interactions	High BMI			
	Coffe vs Juice		Mate vs Juice	
	Disgust	Joy	Disgust	Joy
Drink (df = 1)	8.814 **	2.189 ns	4.783 *	4.380 *
Sip (df = 2)	1.096 ns	1.137 ns	1.077 ns	0.471 ns
Seconds (df = 2)	1.508 ns	1.305 ns	0.073 ns	1.903 n.s.
Drink x Sip (df = 2)	1.281 ns	1.048 ns	1.256 ns	2.467 n.s.

Drink x Sec (df = 2)	0.665 ^{ns}	0.697 ^{ns}	1.316 ^{ns}	1.129 $^{n.s.}$
Sip x Sec (df = 4)	0.589 ^{ns}	0.294 ^{ns}	0.843 $^{n.s.}$	0.305 $^{n.s.}$

Factors and interactions	Normal BMI			
	Coffe vs Juice		Mate vs Juice	
	Disgust	Joy	Disgust	Joy
Drink (df = 1)	1.602 ^{ns}	0.012 ^{ns}	11.677 ***	0.003 ^{ns}
Sip (df = 2)	2.270 ^{ns}	1.000 ^{ns}	0.130 ^{ns}	0.925 ^{ns}
Seconds (df = 2)	0.319 ^{ns}	7.166 ***	0.111 ^{ns}	2.978 ^{ns}
Drink x Sip (df = 2)	1.213 ^{ns}	2.669 ^{ns}	0.418 ^{ns}	3.658 *
Drink x Sec (df = 2)	1.820 ^{ns}	0.117 ^{ns}	1.585 ^{ns}	2.165 ^{ns}
Sip x Sec (df = 4)	0.905 ^{ns}	0.855 ^{ns}	0.550 $^{ns.}$	0.184 ^{ns}

df = degrees of freedom, ns = not significant, * p <.05, ** p <.01, *** p <.001

Figure captions

Figure 1. Intensity of the disgust (a, c) and joy (b, d) reaction for High and Normal BMI comparing coffee, mate and juice from three consecutive sips (Sip 1: initial, Sip 2: 20, Sip 3: 40 seconds) evaluating each sip at 1-, 5- and 10-seconds. Mean ± SEM

Figure 2. Time series analysis of disgust (a, b) and joy (b, c) in facial expression of High BMI group, comparing coffee and mate vs juice (baseline). Each percentage (%) represents the time period where the intensities of emotions between the drinks presented significant differences. The dotted lines show for above the timeline the greater differences for coffee or mate and, below the timeline the greater differences for juice. The percentages underlined correspond at the 60 seconds of the entire test.

Figure 3. Time series analysis of disgust (a, b) and joy (b, c) in facial expression of Normal BMI group, comparing coffee and mate to juice (baseline). Each percentage (%) represents the time period where the intensities of emotions between the drinks presented significant differences. The dotted lines show for above the timeline the greater differences for coffee or mate and, below the timeline the greater differences for juice. The percentages underlined correspond at the 60 seconds of the entire test.

Informed consent for facial expression video recording

Responsible researcher: Dra. María Clara Zamora
Sensory Analysis Laboratory, Faculty of Engineering and Agricultural Sciences, Argentine Catholic University (UCA). Alicia Moreau de Justo 1500, Buenos Aires. Email: czamora@uca.edu.ar

PURPOSE: To study the perception and acceptance of bitter taste in people with different BMI, using bitter drinks (coffee, yerba mate infusion and grapefruit juice) and applying facial expression video recording

PROCESS: Facial reactions during consumption of three drinks will be videotaped with a digital video camera (JVC GZ-MS150SU), which will be located directly above the computer screen and in front of the subject at 1.5 m, in order to film only the face.

The videos will last 10 minutes and will be analyzed by the FACETTM SDK program (iMotions Inc., Cambridge Innovation Center, E.E. U.U.). Once the data is obtained, the videos will be deleted.

BENEFITS: The study of perception and preference to bitter taste, and the registration of facial expressions before drinks with different intensity of bitterness, represents a contribution regarding the implementation of new methodologies. It is expected to deepen the knowledge of preferences regarding the selection of foods, and if the condition of overweight influences or determines the type of diet that is adopted. This will allow in the future to implement intervention programs both in healthy populations (children and adolescents) and clinics (people with obesity, eating disorders).

RIGHTS AS A RESEARCH PARTICIPANT: My participation in this study is completely voluntary. The information obtained will be treated completely confidential and my identity will be protected with a code. Only the research staff involved in this study will have access to such information (Personal Data Protection Law 25,326).

My personal information is necessary so that they can contact me if I am selected for a later phase of this study. If they so wish, they will be able to receive information on the results obtained through published scientific papers. The data will be analyzed together, so that your personally identifiable data will not be found.

CONFORMITY: I have read and voluntarily accept to participate.

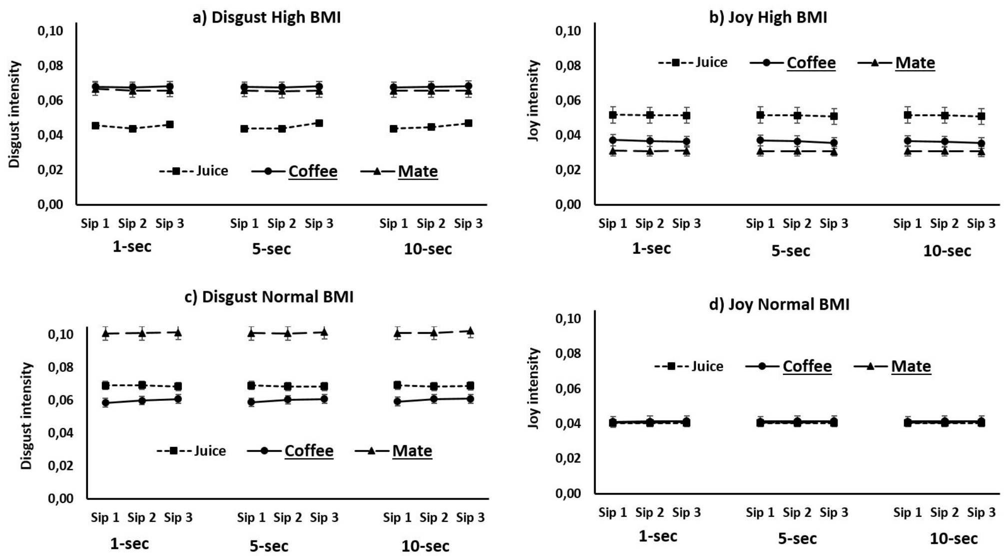
Sign:

Telephone or email for contact:

Researcher's commitment to respect the internal ethical standards on research with human beings

As a researcher responsible for the project, in relation to the commitment of ethical responsibility that I assume to carry out the research, declare that the participants: They do not live, work or are in circumstances that imply social conflict, They do not live or work in circumstances that imply risks for personal integrity or health and does not include minors, people with mental disabilities, illiterate.

Consent Form was approved by the Ethics Committee of the Pontificia Universidad Católica Argentina



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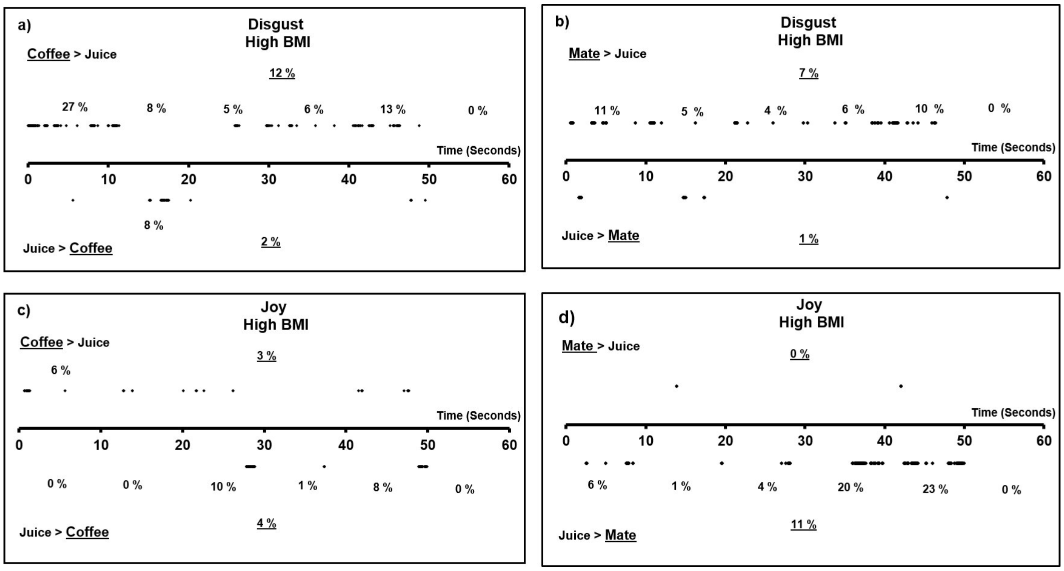

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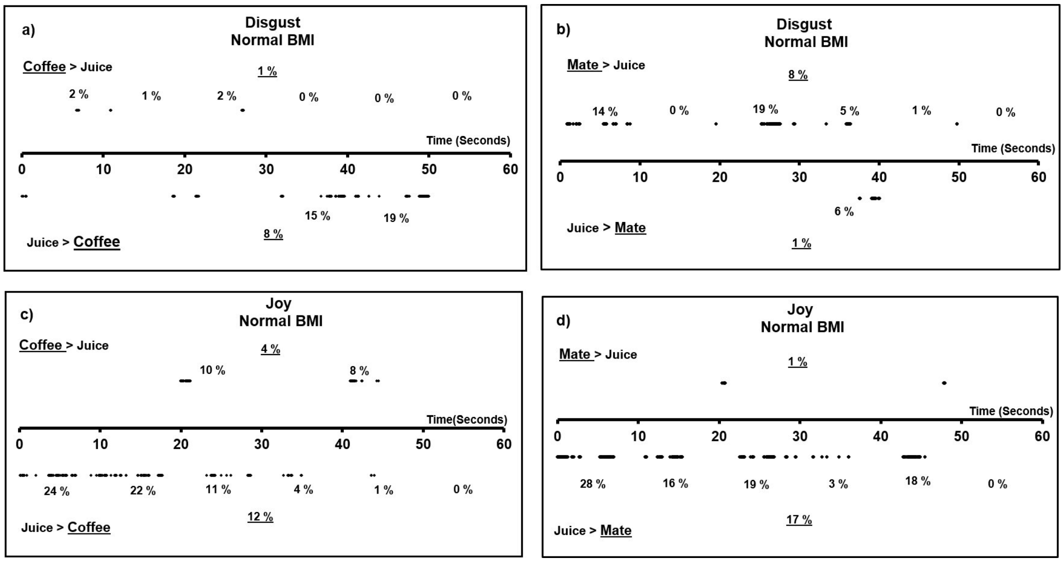

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