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Impact of music on the dynamic perception of coffee and evoked emotions evaluated by temporal dominance of sensations (TDS) and emotions (TDE)

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ABSTRACT

The aim of the present work was to study the temporal effect of music on sensory perception and on the emotional changes while drinking coffee. Two different commercial filter coffees were evaluated by a group of 48 consumers using the Temporal Dominance of Sensations (TDS) method. The description was performed in silence and also while listening to two different musical fragments: one with a "sweet" connotation and the other with a "bitter" one. Under the same conditions (drinking coffee with and without musical stimuli), a different group of 72 consumers evaluated their perceived emotions (*joy, fear, neutral, rejection, disgust, surprise, sadness* and *anger*) by Temporal Dominance of Emotions (TDE). Data was analyzed by dominance curves and by ANOVA and MANOVA of the durations of dominance (for emotions and sensations). Coffee perception, in both cases, was modified by the musical stimuli. The duration of dominance of *bitter* was increased in the presence of "bitter" music, while it decreased with the "sweet" music. Moreover, the *sweet* attribute was practically not chosen for describing the coffee on its own, but its choice and duration as dominant increased while listening to the "sweet" musical fragment. Music had a larger impact on the perceived emotions. The "sweet" music was related to the emotion of *joy*, which was accompanied by *surprise* and also some *sadness* when drinking coffee (regardless of the type of coffee being drunk). The "bitter" music was linked to the emotions *anger* and *fear*. The effect of "sonic seasoning" and translation of emotions with a familiar product was observed.

1. Introduction

Eating is a multisensory experience, even if sometimes we are not fully aware of it. Sight, sound, smell, taste and touch provide, in an integrated fashion, all the information we need before and during food and beverage consumption. Moreover, the different senses can be stimulated by sensory cues coming from other than the food itself (e.g. context). In crossmodal interactions, what impacts one sense, influences what is experienced by another. These can go from the impact of illumination on taste (e.g. the use of a red light to make a wine taste fruitier and sweeter, Spence, Velasco, & Knoeferle, 2014), to the influence of furniture in a bar on consumers' drink choice (Sester et al., 2013). In the present work, the impact of musical fragments on perceived temporal profile of coffee was studied.

Empirical research shows that there are correlations between music and basic tastes. Sweet taste tends to be conceptually matched with sounds that are high in pitch, with slow tempo music that is *"legato"* in articulation (i.e. continuous and without separation between successive sounds), soft in dynamics and with consonant harmonies (Bronner et al., 2012; Mesz et al., 2011). By contrast, sour taste tends to be matched with extremely high-pitched sounds, fast tempo, and dissonant music. Bitter taste is associated with sounds that are low in pitch and more likely to be brassy (Crisinel & Spence, 2010; Wang et al., 2015). Salty taste is mostly related with *"staccato"* music (i.e. music with clearly detached successive notes) (Mesz et al., 2011; Knöferle& Spence, 2012; Guetta & Loui, 2017), and with long decay time, high auditory roughness and a regular rhythm (Wang et al., 2021). Interestingly, the same correspondences have been documented in non-western cultures (Knöeferle et al., 2015).

Other research on the impact of music on food preference, showed that, when presented together, the music tends to enhance the pleasure

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of what one is tasting, affects food selection and orients visual attention to crossmodally congruent food items (de Paula et al, 2021; Peng-Li et al, 2020; Spence, Velasco, & Knoeferle, 2014; Wang et al., 2015; Zellner et al, 2017). It has been shown that the experience of many different food and drink products can be modified by changing the music or soundscape that people listen to (Wang & Spence, 2015a, 2015b, Crisinel et al., 2012; Reinoso Carvalho, Van Ee, Rychtarikova, Touhafi, Steenhaut, Persoone & Spence, 2015; Reinoso Carvalho, Van Ee, Rychtarikova, Touhafi, Steenhaut, Persoone, Spence, & Leman, 2015; Spence & Deroy, 2013; Spence, Velasco, Vanne, & Hopia, 2014; Velasco et al., 2013; Hauck & Hecht, 2019); for a summary of recent studies on this subject see Spence et al. (2019).

This effect of music on taste perception and appreciation is known as "sonic seasoning" (Spence, 2013; Spence et al., 2019) and it tends to be more pronounced for foods with complex flavors, this being explained by an attentional account. Taste-congruent soundtracks draw the listener's attention towards the taste that corresponds to the soundtrack enhancing the salience of the attended characteristic. "Sonic seasoning" is said to work comparatively better with unfamiliar food products (Spence et al., 2019), in which case the role of memories of previous experiences will presumably not dominate over the actual tasting situation, giving a higher predominance to the impact of sound. However, it has been observed with familiar and frequently consumed products such as cheese, chocolate, wine, beer, and most relevantly for the present study, coffee (Spence et al, 2021).

Besides attentional biases, there are several other plausible mechanisms accounting for the effect of sound in taste perception and evaluation (Wang, 2017), such as transference. This is the case where the preference for the music is transferred to the preference on taste. People will like more a food or drink consumed while listening to music they enjoy in comparison to eating/drinking it with music they do not. In fact, several studies have shown this transference for a variety of products such as fruit juice, chocolate and beer (Reinoso Carvalho, Van Ee, Rychtarikova, Touhafi, Steenhaut, Persoone & Spence, 2015; Reinoso Carvalho, Van Ee, Rychtarikova, Touhafi, Steenhaut, Persoone, Spence, & Leman, 2015; Wang, 2017; Reinoso-Carvalho et al., 2019). Moreover, in a study by North (2012) on music and wine, it was found that some characteristics were transferred from the music to the wine: music that was judged as heavy and powerful made a wine taste heavier and more powerful. However, no further research was done regarding the aspects of emotions evoked by music or soundscapes and their combination with food or beverage intake.

Since music and food consumption are both time-varying in nature, it would seem appropriate to use a temporal method for studying the impact of music on the perception of food and drink. A recent study used time-intensity (T-I) to measure temporal changes in sweetness and sourness evaluations of an off-dry white wine when the music stimulus changed from a soundtrack commonly associated with sweetness to one associated with sourness instead, and vice versa (Wang et al., 2017). Results revealed that a change of soundtrack resulted in a change in taste intensity (for both sweetness and sourness) in the same direction as the change in the soundtrack. More specifically, a switch from the sweet to the sour soundtrack enhanced the intensity of sourness, whereas a switch from the sour to the sweet soundtrack enhanced the perceived intensity of sweetness.

More complex shifts in the taste of red wine presented together with classical and pop music were measured with the method Temporal Dominance of Sensations (Wang et al., 2019). Temporal Dominance of Sensations (TDS, Pineau et al., 2003) is a multi-dimensional dynamic technique which is easily used with consumers, allows description in an holistic way and has successfully been used to describe perception of coffee (Dinnella et al., 2013). Moreover, TDS description is based on pointing out (from a given list) the sensation that most catches the evaluator's attention at every moment of the tasting. It is a task of choice, based on attentional behavior and is not a descriptive technique based on quantifying the intensity of the perceived sensations. Therefore, it is adequate to see if music changes our attention in relation to basic taste when consuming a product, in this case, coffee. In addition, this method has been easily adapted to obtain information on emotions (Temporal Dominance of Emotions, TDE, Jager et al. (2014)). In this way, the two methods based on temporal choice can be used to evaluate how: a) consumers perceive the coffee with and without musical stimuli and b) how consumers perceive and describe their own emotions while drinking coffee with and without the same musical stimuli.

It was the aim of the study to evaluate the dynamic impact of two different sound fragments on coffee tasting. Temporal changes in taste perception of coffee were evaluated by means of Temporal Dominance of Sensations (TDS) while the impact on self-reported emotions was described by Temporal Dominance of Emotions (TDE).

2. Materials and methods

The experiment took place in the sensory facilities of *the Facultad de Ingeniería y Ciencias Agrarias (Universidad Católica Argentina, Buenos Aires)* which has nine sensory booths equipped with special lighting and tablets using the TimeSens software (INRA, Dijon, France).

2.1. Coffee samples

Two different commercial filter coffees were used. They were bought at a local supermarket and were both of the same commercial brand (*Sensaciones* by *Bonafide,* made in Argentina). According to the description of the manufacturer, they were different in terms of intensity and aromatic profile. One was defined as "intense" and the other one as "soft" (hereon coffee samples will be referred to as IC and SC respectively). However, the aim of having two coffee samples was to verify the impact of the musical stimuli on coffee perception, not to compare them.

Coffees were prepared according to the manufacturers' instructions: 12 g of coffee every 200 ml of water using a traditional filter coffee machine. They were served at 52 ± 5 °C in small disposable coffee cups coded with random three digit numbers.

2.2. Music fragments

The musical stimuli consisted of two fragments of 20 s each, with "sweet" and "bitter" connotations.

The "sweet" fragment combined the beginning of Robert Schumann's Eusebius from his Carnaval Op. 9 and the beginning of the sweet soundtrack designed by Jialing Deng and Harlin Sun for Deng's Master of Arts thesis. The "bitter" audio was also a combination of two different soundtracks, a fragment from the beginning of the first movement of the Third Symphony by H. Górecki and a static low-register trombone chord. The audios were selected to satisfy criteria associated with sweetness and bitterness in the literature (Mesz et al., 2011; Knöferle & Spence, 2012). They were harmonically consonant, of medium to high pitch and of low psychoacoustic roughness in the case of "sweet" audio, and low-pitched and of high roughness in the case of "bitter" audio. Moreover, in the case of "sweet" music, both the Schumann and the Deng fragments had been used in previous research and had shown to reliably evoke sweetness (Kontukoski et al., 2015; Wang et al., 2015). Both the "sweet" and the "bitter" music were validated in an online experiment where a total of 24 musical fragments (6 intended to correspond to each taste category: bitter, salty, sour and sweet), were presented to 18 participants who were asked to determine, in a forced choice, to which of the taste category corresponded each fragment. For each "sweet" and "bitter" fragment, 83% or more of the participants associated the intended taste.

From hereon, musical stimuli will be referred to as SM, for the "sweet" fragment and BM, for the "bitter" fragment.

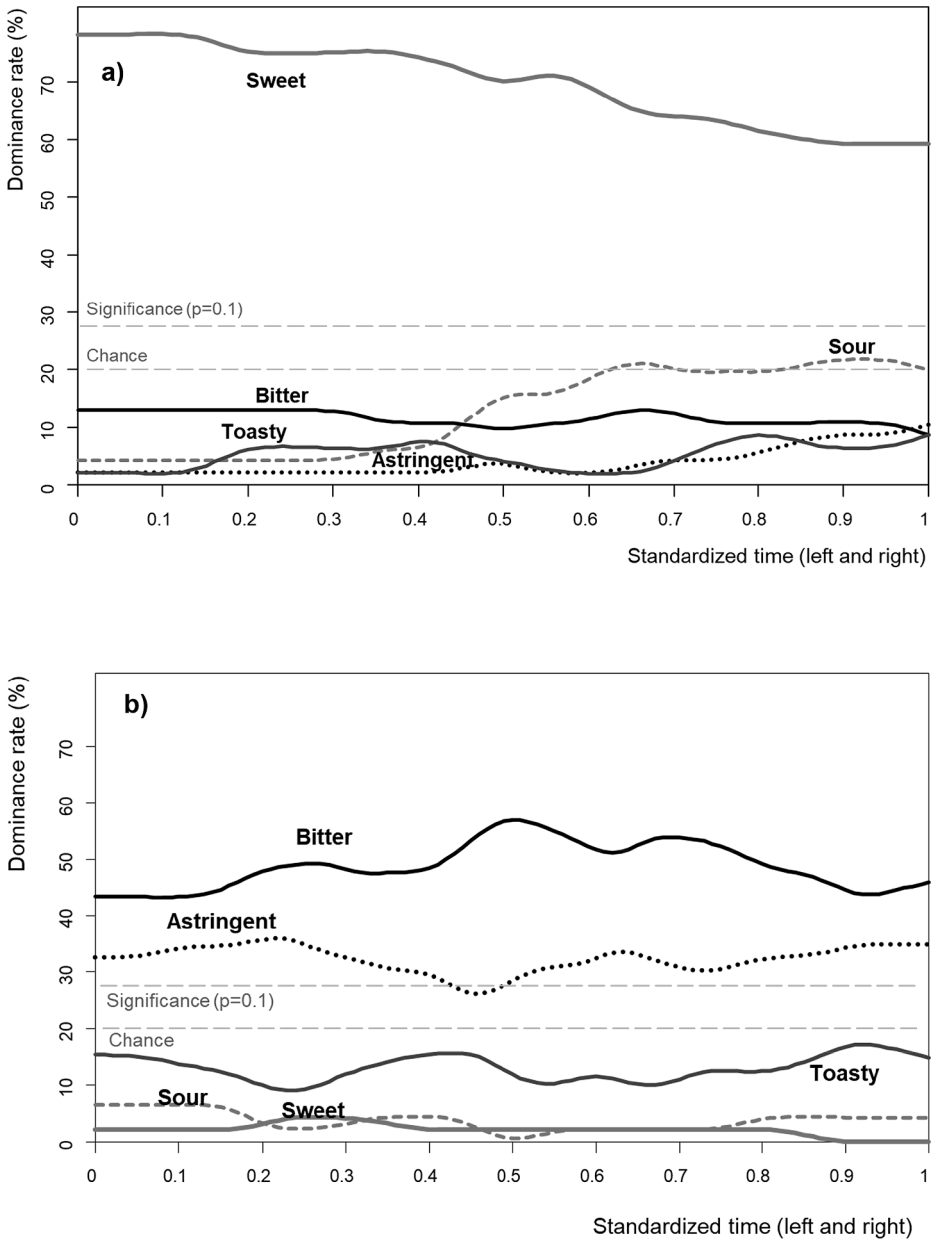


Fig. 1. TDS curves of the musical fragments. a) SM, "sweet" musical fragment; b) BM, "bitter" musical fragment.

2.3. Consumer panels

A total of 120 frequent coffee consumers were recruited by mail from the sensory analysis laboratory database. They were students and staff members of the *Universidad Católica Argentina* who consumed black coffee at least once a day, without any added sugar or sweetener.

Consumers were randomly assigned to the Temporal Dominance of Sensations (TDS) or the Temporal Dominance of Emotions (TDE) group. The final panels were conformed as follows: 48 consumers (72% women, mean age 32 years old, ± 11.8) for TDS and 72 consumers (72% women, mean age 29 years old, ± 10.6) for TDE.

Sample size calculation was based on exploring the relationship between two musical fragments and the sensations (TDS) or emotions (TDE) to two samples of coffee using the software G*Power (version 3.13; Cárdenas & Arancibia, 2014). Assuming two-sided tests with $\alpha = 0.05$, power $(1\text{-}\beta) = 0.80$ and effect size $f = 0.18$, in TDS, a sample size of 44 ensures a power > 0.80, $F\ [3, 129] = 2.674$. For TDE, effect size $f = 0.14$, the required sample size would be 71 to ensure a power > 0.80, $F\ [3, 210] = 2.674$.

More participants were allocated to the TDE study since there is more literature on the effect of music on taste sensations (Wang & Spence, 2015a, 2015b, Wang et al. 2019; Reinoso Carvalho, Van Ee, Rychtarikova, Touhafi, Steenhaut, Persoone, Spence, & Leman, 2015) than on its effect on emotions while consuming food or drink products.

2.4. Evaluation methods

2.4.1. Coffee description by temporal dominance of sensations (TDS)

Consumers participated in a short training session and then evaluated all samples (coffee, music fragments and coffee + music fragment combinations) over a one-hour long session.

The training session was devoted to explaining the method and the proposed attributes. Participants were told that the aim of the evaluation was to register the dominant sensation at every moment of the tasting, the dominant sensation being the one that caught their attention, not necessarily the most intense one (Pineau et al., 2003). The panel leader

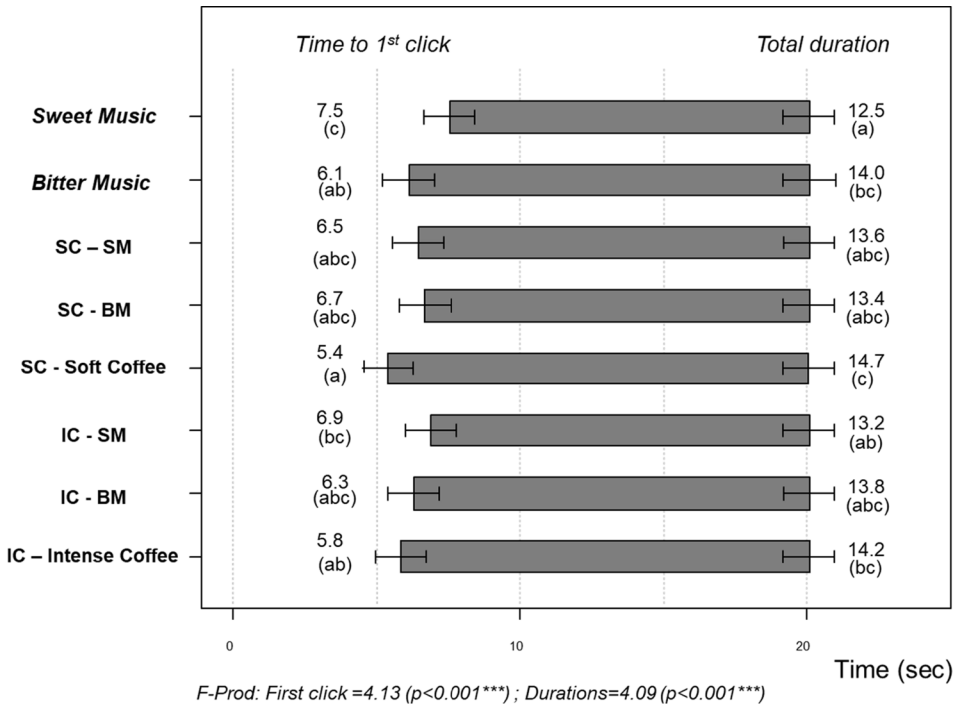


Fig. 2. Time to first click and total duration of the evaluation for all the samples (musical fragments, coffees and coffees with musical stimuli). Different letters between brackets indicate significant differences among samples for time to first click and total duration according to Tukey post-hoc test.

emphasized that the evaluation was dynamic and that data was continuously recorded, from the moment they clicked on a start button until the end of the evaluation (from the first contact with the product in the mouth until after swallowing). Consumers were presented with a list of sensations which included: *sour, bitter, sweet, astringent* and *toasty*. Consumers were also told that they could choose only one attribute at a time, but that the dominant sensation could change as many times as desired. The same descriptor could be used more than once, and some might not be used at all. A live demonstration was carried out to make sure consumers understood the method.

In this training session participants also received basic taste solutions for *sweet*, *sour*, *bitter* and for the mouthfeel sensation *astringent* to ensure that they could identify and differentiate them (specially the last three). Solutions were composed as follows: 2% sucrose (*sweet*), 0.05% citric acid (*sour*), 0.05% caffeine (*bitter*) (Meilgaard et al., 1991), 0.07% alum (*astringent*) (Drobna et al., 2004). For *astringent* they were also told that it is a sensation associated with dryness, puckering and rough mouthfeel.

In the evaluation session consumers were given first a warm-up sample (a third commercial coffee) to familiarize them with the computer program and the methodology. Then, samples were presented as follows: coffee without music (half consumers received IC first), the four combinations of coffee and music (IC + BM, IC + SM, SC + SM, SC + BM) presented in random order and, at the end of the session, consumers were asked to use the same list of attributes to describe the musical stimuli (half the panel began by the SM). For music description, consumers were simply asked the following: "if you were to describe this musical fragment with the given attributes: which ones would you use?". This was done at the end of the session in order not to bias consumers' responses when tasting the coffee together with the musical fragments. The order of the attributes presented on the screen was randomized across consumers to reduce potential bias due to attribute position (Pineau et al., 2012). However, for each participant, the order was kept constant across samples.

With each evaluation consumers were given a new coffee sample with a different number. In every case, they were asked to take one generous sip and the evaluation was stopped after 20 s, in accordance with the duration of the musical fragment (this was the same in the absence of music).

2.4.2. Evoked emotions described by temporal dominance of emotions (TDE)

The self-reported emotions while consuming the coffee with and without musical stimuli were evaluated by Temporal Dominance of Emotions (TDE) (Jager et al., 2013). The principle behind TDE is like that of TDS, therefore similar instructions were given to the group performing this evaluation. Moreover, consumers were instructed to focus on how they felt at every moment, regardless of whether they felt like that because of the music or the coffee.

The list of emotions was reduced and included *joy, fear, neutral, rejection, disgust, surprise, sadness* and *anger*. These were based on Ekman's study on basic emotions (Ekman, 1999). Water was used as a baseline and warm-up sample for consumers to get acquainted with the software and method. Sample presentation followed the same order as in the TDS evaluation (only coffee, combinations of musical fragments + coffee, and musical fragments alone).

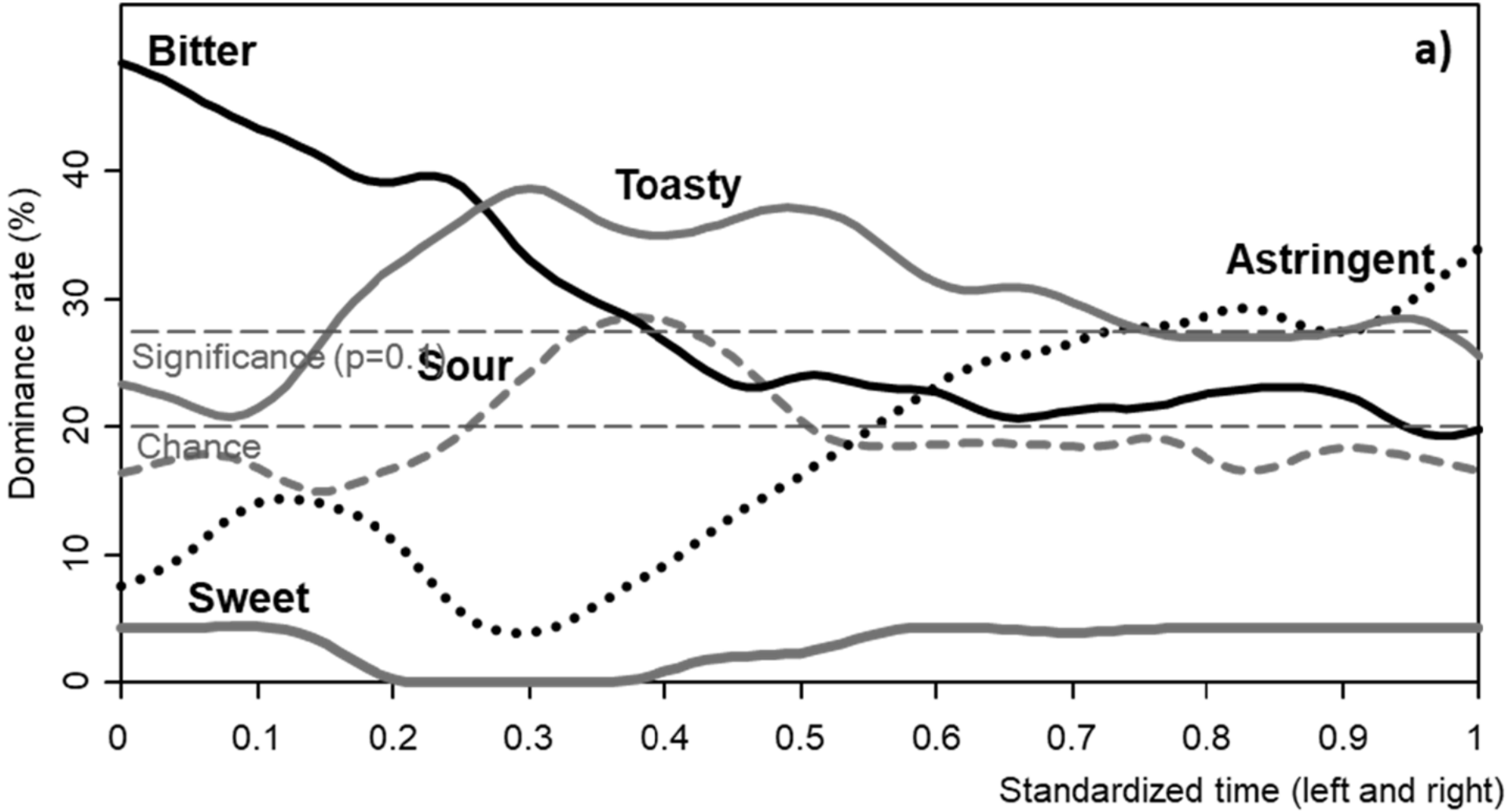
The order of the emotions on the screen was also randomized across consumers to reduce potential bias due to position (Pineau et al., 2012). For each participant, the order was kept across samples.

2.5. Data analysis

Data was mostly analyzed by means of the web based TimeSens software (INRA, Dijon, France).

The effect of the presence of music on the TDS and TDE task was assessed by evaluating differences in time to first click (and consequently real duration) in all the evaluations.

The temporal description of the musical fragments and of the selected coffees was depicted by the construction of dominance curves (Pineau et al., 2009), displaying the proportion of the consumers who selected a certain attribute as dominant at a given moment. The same was done with the temporal data on emotions. Curves were standardized to the left to reduce differences among subjects and to the right, since all the evaluations ended after 20 s, in agreement with the duration of the music fragment.


Bitter
a)
Toasty
Astringent
Sour
Significance (p=0.1)
Chance
Sweet
Dominance rate (%)
0
10
20
30
40
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Standardized time (left and right)

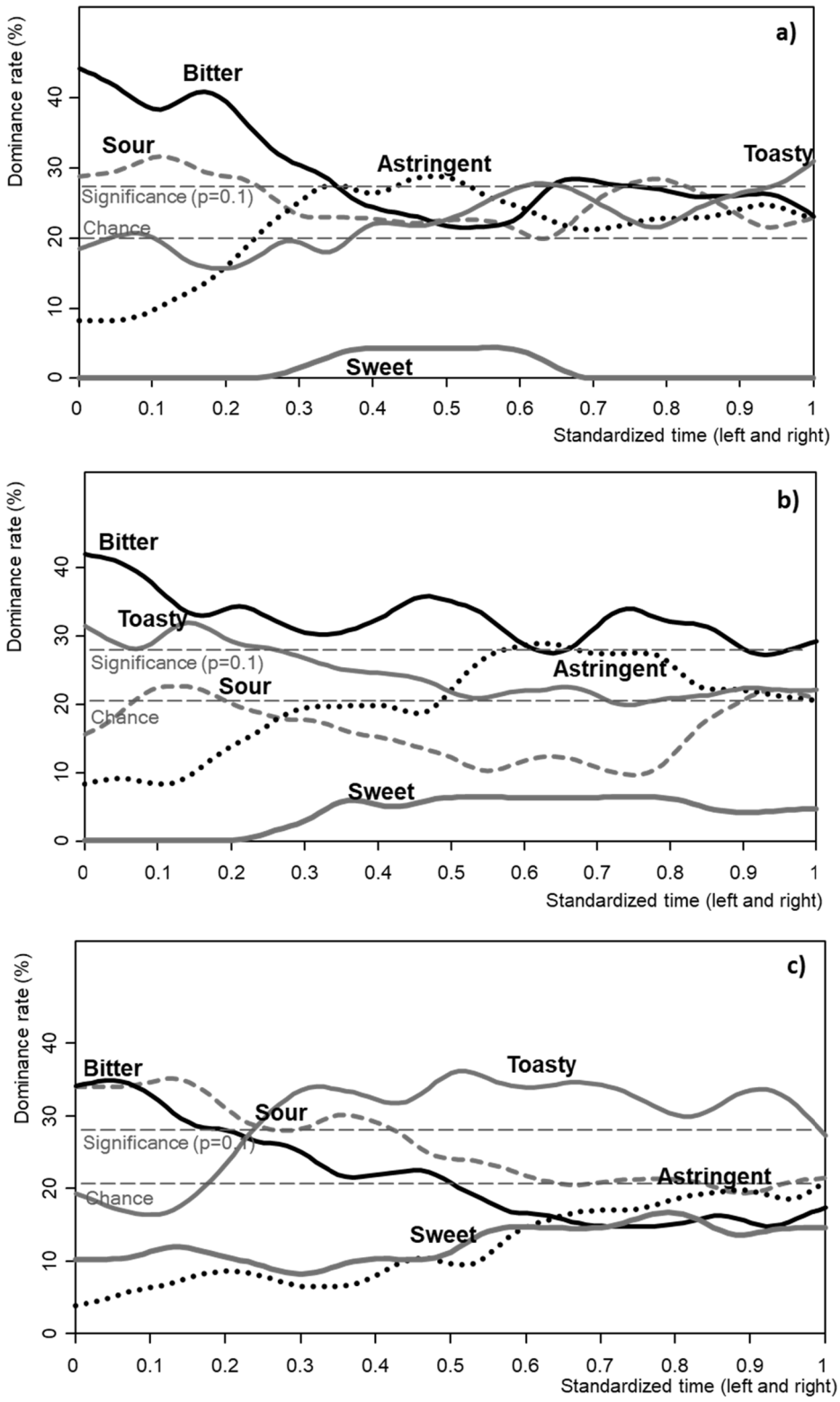


Fig. 4. TDS curves for a) IC (intense coffee without music), b) ICBM (intense coffee with bitter musical fragment) and c) ICSM (intense coffee with sweet musical fragments).

fragment was also described as *astringent* by some of the consumers. *Sour* and *toasty* were never significant. There was a high agreement (dominance rate over 60%) on the use of the term *sweet* for describing the "sweet" soundscape. For the "bitter" musical stimulus, the attribute *bitter* had the highest dominance rate, but consumers also used (in a smaller proportion) the term *astringent*. The use of this latter term could be explained by the high perceived roughness of the sound which also agreed with the definition given for *astringent* (sensation associated with dryness, puckering and rough mouthfeel, Section 2.4.1). Also, rough timbre has been shown to be processed by the same neural substrates involved in feeling and talking about rough objects (Wallmark & Kendall, 2018).

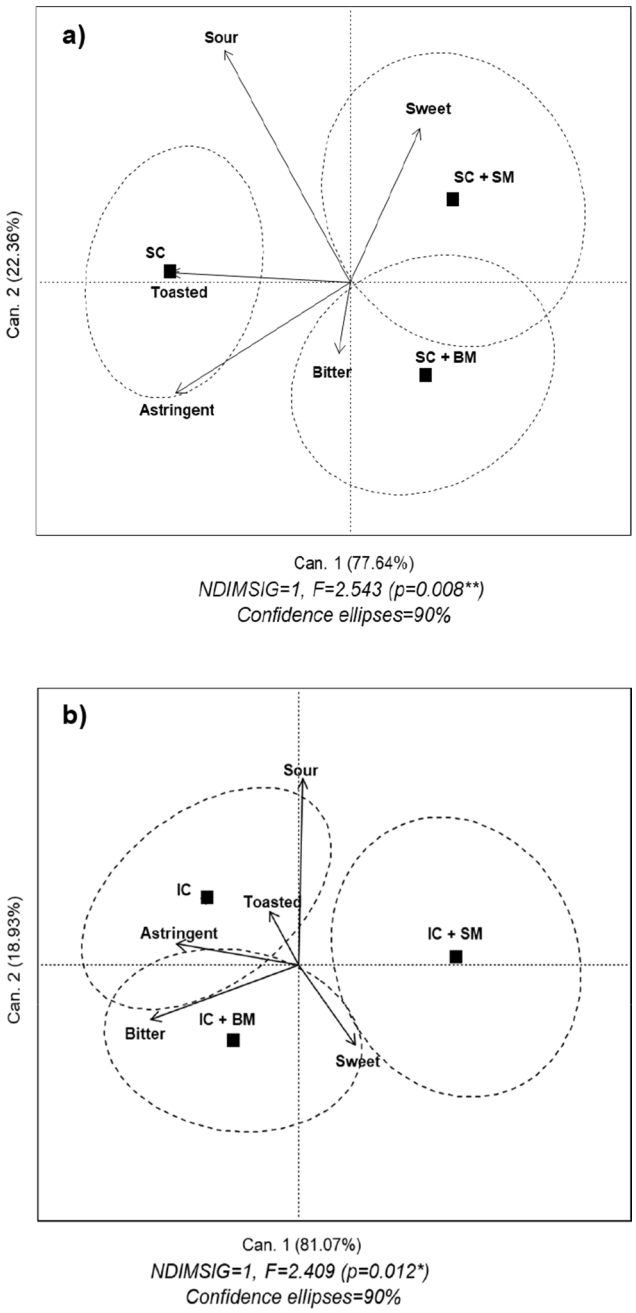


Fig. 5. Canonical Variate Analysis (CVA) for: a) the soft coffee (SC) evaluated without and with musical fragments (SM and BM) and the same for b) the intense coffee (IC).

Fig. 2 shows a comparison on the mean time before the first click and the real duration of all the evaluations. It can be observed that consumers took the longest time to give the first click for the "sweet" music fragment and this was significantly different from the "bitter" music, to which they reacted faster (7.6 s vs. 6.3 s). Even though consumers were probably surprised to use the taste attributes to describe only the music, they were perfectly capable of doing so.

3.2. Coffee dynamic description without and with background musical stimuli

The temporal description of the sequence of dominant sensations for the evaluation of coffees, without and with the different musical fragments, is presented in Figs. 3a–c and 4a–c.

Table 1
Mean duration of dominance (expressed as a percentage of the evaluation, not in seconds) for TDS attributes. a) Comparison of the soft coffee tasted under the three conditions (no music, SC; "sweet" music (SCSM) and "bitter" music (SCBM). b) Comparison of the intense coffee tasted under the three conditions (no music, IC; "sweet" music (ICSM) and "bitter" music (ICBM).

a)	SC	SCSM	SCBM
*Sweet**	3 (a)	11 (b)	7 (ab)
*Bitter**	29 (a)	37 (ab)	40 (b)
Astringent	18	10	15
*Sour**	20 (ab)	18 (ab)	12 (b)
Toasty	30	24	26
b)	**IC**	**ICSM**	**ICBM**
*Sweet**	1 (a)	11 (b)	6 (ab)
*Bitter**	30 (ab)	21 (a)	33 (b)
Astringent	21	12	20
*Sour**	25 (b)	26 (b)	16 (a)
Toasty	23	30	25

Different letters show significant differences among samples for the given attributes for Tukey test.
*$p < 0.05$.

The soft coffee (SC) (Fig. 3a) had a more complex profile with a higher agreement among consumers. The *bitter* taste was perceived as dominant at first, then *toasty* called their attention, ending with an *astringent* note. Sour was slightly dominant in the middle of the tasting. On the other hand, the intense coffee (IC) (Fig. 4a) was mostly characterized by *bitter*. Sour was also significant at the beginning (with a smaller dominance rate), and *astringent* and *toasty* were chosen by the consumers, reaching the limit of significance, but *sweet* was practically not selected as a dominant attribute.

The impact of the music on the sequentiality and on the dominance rate of the sensations can be observed in Fig. 3b and c for the SC and in Fig. 4b and c for IC. When described with the "bitter" musical fragment, the dominance rate of *bitter* increased in both coffees and it even became the only attribute above significance all along the tasting (Figs. 3b and 4b). The use of a "sweet" musical fragment had the opposite effect on bitterness reducing its dominance rate. This was more evident in the IC. Moreover, even though it did not reach significance, it can be observed that with the "sweet" music, the dominance rate of *sweet* increased in both coffees. In all cases the temporal profiles of the coffees changed under the three tasting conditions.

To find the impact of the auditory stimulus on small differences, the duration of dominance of the different attributes were also evaluated and represented with a Canonical Variate Analysis (Galmarini et al., 2017) comparing each coffee sample evaluated under the three different conditions. These are presented in Fig. 5a and b.

As can be observed in the figures, coffee perception was modified by the musical fragments. The obtained description for each coffee was different under the three conditions (SC: F-MANOVA = 2.5, p = 0.008**; IC: F-MANOVA = 2.4, p = 0.012*). In both cases the musical stimuli changed coffee perception mostly in the direction of the characteristic of the musical fragment. In this figure, the length of the vectors represent differences among samples, the longer the vector the bigger the difference in duration of dominance for this descriptor among the samples. The duration of *sweet* as dominant was significantly longer when the coffee was tasted while listening to the "sweet" music. On the other hand, the duration of *bitter* was significantly longer when the coffee was evaluated while listening to the "bitter" music. The duration of each attribute (as a proportion of the evaluation) was also compared in an ANOVA, for each coffee under the three tasting conditions. This is presented in Table 1 (part a) comparisons for SC; part b) comparisons for IC).

Table 1a and b shows that, under the three tasting conditions, there were significant differences in the duration of dominance for the attributes *sweet, bitter* and *sour*. *Toasty* and *astringent* showed no significant

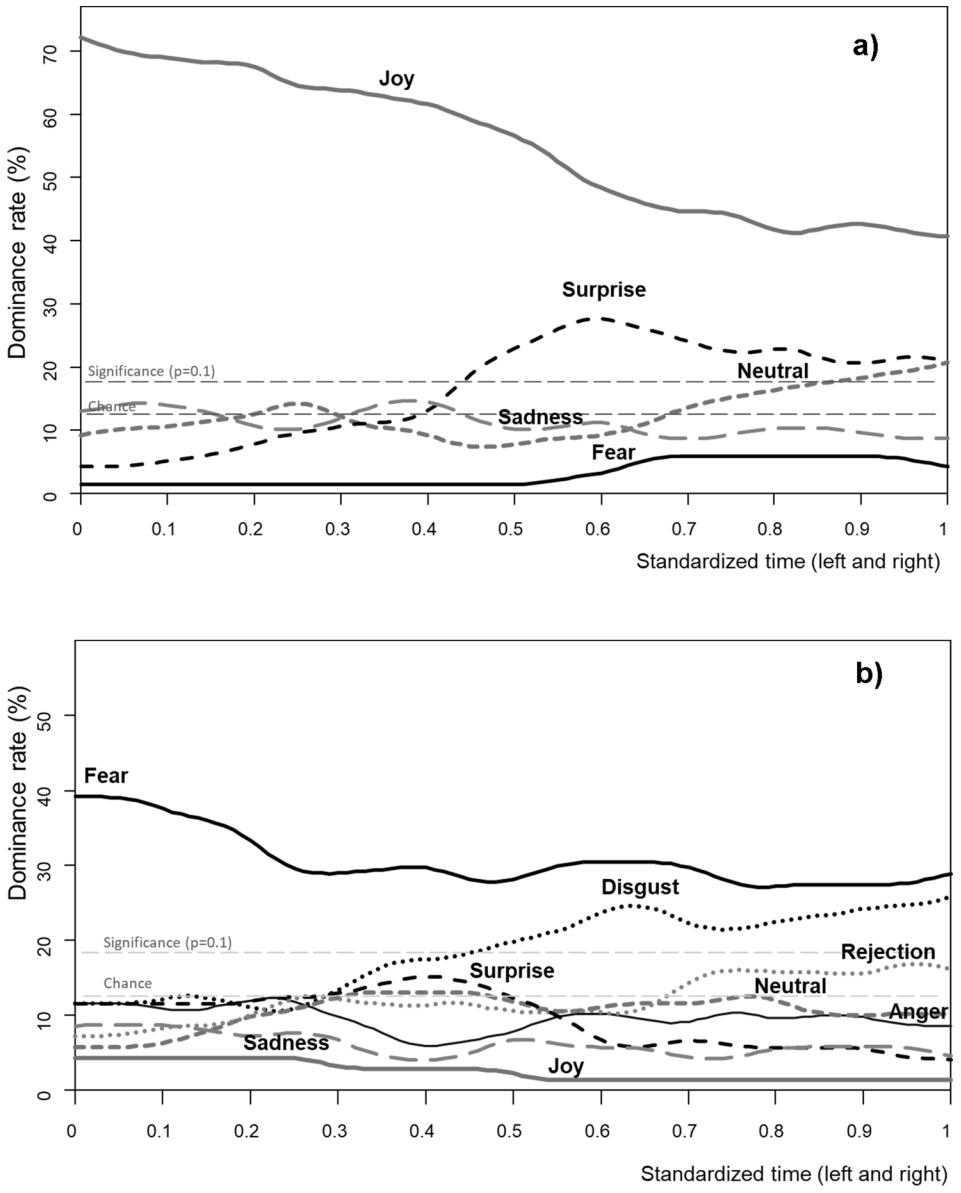


Fig. 6. TDE curves of the musical fragments. a) SM, "sweet" musical fragment; b) BM, "bitter" musical fragment.

differences in terms of total duration (though there were differences in dominance rate (panel agreement), see Figs. 3 and 4).

In both coffees, there was a significant difference in the duration of *sweet* and the highest values were observed while listening to the "sweet" music. However, there was also a small effect of the "bitter" music increasing the duration of *sweet*, though it was not significantly different from the coffee with no music. Changes in *bitter* were higher while listening to the "bitter" musical fragment, but they were not the same in both coffees. Finally, the duration of *sour* was reduced in the presence of both musical fragments, probably due to the fact that the other sensations increased their duration and that there was no association with the musical fragments. The nature of the musical fragment drove most of the changes in the description. However, there is probably also a music effect (regardless of the nature of the musical fragment) which could be further explored in future experiments.

3.3. Description of evoked emotions

Emotions evoked by the two musical fragments were quite different. The corresponding TDE curves are presented in Fig. 6a and b.

The "sweet" music fragment had an important dominance of *joy* and some *surprise*. On the other hand, the "bitter" fragment was associated with more negative emotions: mainly *fear*, and *disgust*. In the TDE curve for water (warm up sample, graphic not shown) the only evoked emotion was *neutral*, showing that consumers understood the method and that they were not projecting a previous emotion onto the evaluation.

The impact of the musical fragments on the perceived emotions while tasting each coffee was evaluated by analyzing the duration of dominance of the emotions as presented in Fig. 7a and b.

The F-values for the MANOVA analysis (Fig. 7a and b) show a greater discrimination for the samples by TDE than by TDS. Moreover, coffee evaluation reflect the emotions evoked by the music. For both coffees it was found that the prevailing emotion when describing the coffee alone was *neutral* (that was the emotion that was dominant for a longer period of time). Also, when tasting the coffee with the "bitter" musical fragment the emotions of *fear* and *anger* were dominant for longer periods of time while with the "sweet" music *joy, surprise* and also *sadness* prevailed. This was similar for both coffees.

As complementary information, Table 2a and b presents the

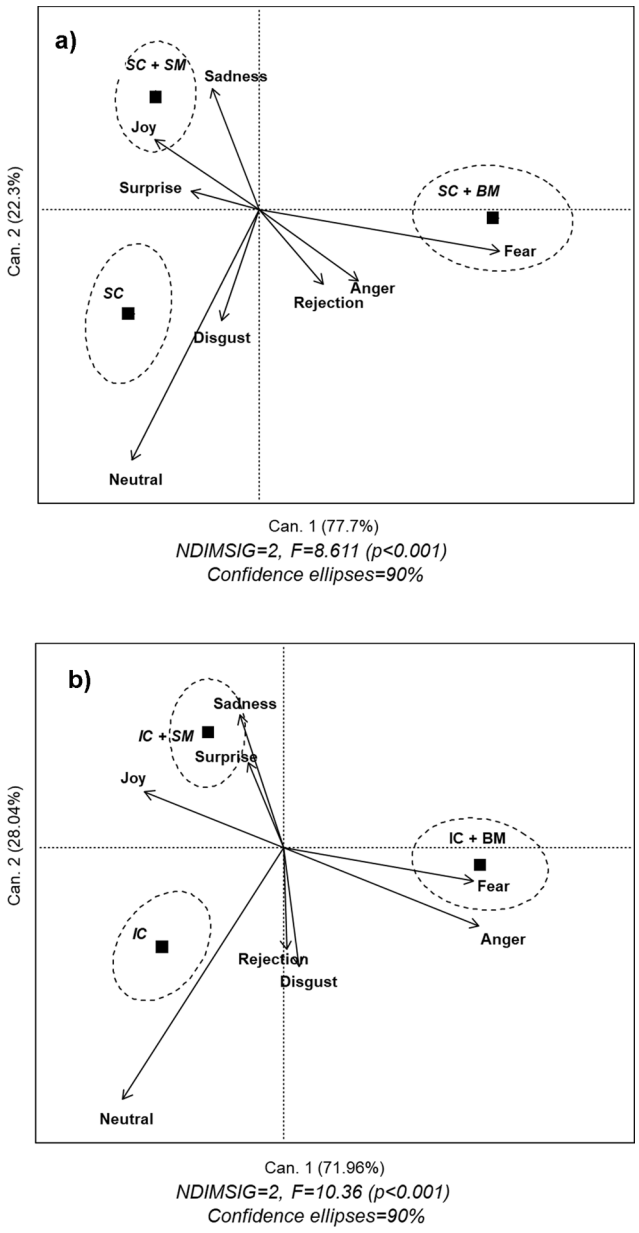


Fig. 7. Canonical Variate Analysis (CVA) for the duration of dominance of the emotions: a) soft coffee (SC) evaluated without and with musical fragments, b) the intense coffee (IC) without and with musical fragments.

comparison of the duration of dominance by emotion for each coffee tasted under the different conditions and the musical fragments. Significant differences were found in the duration of all emotions.

Fear was not registered while tasting only coffee. This emotion was linked to the "bitter" musical fragment and the tasting of the coffees while listening to it (ICBM, SCBM) On the other hand, joy was dominant for a short period of time during the coffee evaluation without music, but its duration increased significantly while listening to the "sweet" music. The neutral emotion, which was registered as dominant for both coffees when there was no auditive stimuli, was significantly reduced with the sonic seasoning. Music made evaluators prone to select other emotions mostly music related; they did not remain indifferent to the music.

4. Discussion

In the present work the impact of auditory stimuli (in the form of musical fragments with a "bitter" and "sweet" connotation) on the perception of the flavor of two different coffees as well as on the emotions experienced while drinking these coffees was evaluated using a temporal method based on the temporal dominance paradigm. Several interesting facts were observed.

First, it was found that consumers were able to describe the proposed musical fragments in a consistent way using the list descriptors proposed for the coffee. Music was susceptible to be described in terms of taste attributes, which shows how "natural" and common are these cross-modal associations.

Surprisingly, consumers chose the first descriptor faster for the "bitter" than for the "sweet" music. This could be related to the intrinsic negative connotation of *bitter* taste which results in a fastest reaction time (Bianchi et al., 2018).

In both coffees, listening to the "sweet" music reduced the dominance of *bitter* and increased the choice of *sweet* as a dominant sensation. This observation makes us hypothesize that, under given conditions, the appropriate sound stimuli could result in, for example, reduction of sugar ingestion by taking advantage of "sonic sweetening".

Moreover, the impact of music was higher on the perceived emotions than on taste. It was found that music drives emotions and that greater differences were expressed for a same coffee based on emotions than on taste. Fig. 8 shows how different the impact of music is on perceived coffee sensations (part a, TDS) and on consumers' emotions (part b, TDE). Even though it was not the aim of the experiment to compare the results between coffees, both are represented on the CVA's to make the comparison more robust.

It can be observed that the duration of dominance of *sweet* in the "sweet" music was bigger than in any of the other sample. Something similar, but to a lesser extent, was obtained for *bitter* and "bitter" music. Therefore, in the TDS experiment, the descriptions for the musical fragments are further apart than in the TDE study and are more differentiated from the description of the coffees and the coffees + musical fragments. In contrast, the duration of emotions evoked by the music are closer to those evoked to the combination of music and coffee, while the coffees without any musical stimuli are further away from the other

Table 2
Mean duration of dominance (expressed as a percentage of the evaluation, not in seconds) for the emotions evaluated by TDE attributes. a) Comparison of the intense coffee tasted under the three conditions: no music (IC); with "bitter" music (ICBM), with "sweet" music (ICSM) and the two musical fragments, "bitter" music (BM), with "sweet" music (SM). b) Comparison of the sweet coffee tasted under the three conditions (no music (SC); with "bitter" music (SCBM), with "sweet" music (SCSM) and the respective comparison with the different musical fragments.

a)	IC	ICBM	ICSM	BM	SM
Joy***	15 (ab)	4 (a)	27 (b)	3 (a)	53 (c)
Fear***	1 (a)	19 (b)	5 (a)	30 (b)	4 (a)
Neutral***	38 (b)	9 (a)	12 (a)	11 (a)	12 (a)
Anger***	1 (a)	14 (b)	1 (a)	10 (b)	1 (a)
Disgust***	19 (b)	22 (b)	12 (ab)	18 (b)	1 (a)
Surprise**	14 (a)	15 (a)	28 (b)	10 (a)	16 (ab)
Rejection**	10 (ab)	12 (b)	4 (ab)	12 (b)	1 (a)
Sadness**	2 (a)	4 (ab)	12 (b)	7 (ab)	11 (b)
b)	SC	SCBM	SCSM	BM	SM
Joy***	14 (a)	6 (a)	29 (b)	3 (a)	53 (c)
Fear***	2 (a)	32 (b)	4 (a)	30 (b)	4 (a)
Neutral***	43 (b)	13 (a)	18 (a)	11 (a)	12 (a)
Anger***	2 (ab)	8 (bc)	0 (a)	10 (c)	1 (ab)
Disgust***	12 (bc)	12 (abc)	7 (ab)	18 (c)	1 (a)
Surprise**	17 (ab)	11 (ab)	23 (b)	10 (a)	16 (ab)
Rejection***	7 (ab)	14 (b)	7 (ab)	12 (b)	1 (a)
Sadness**	3 (a)	5 (a)	11 (a)	7 (a)	11 (a)

Different letters show significant differences among samples for the given attributes for Tukey test.
* $p < 0.05$, ** $p < 0.01$, ***$p < 0.001$.

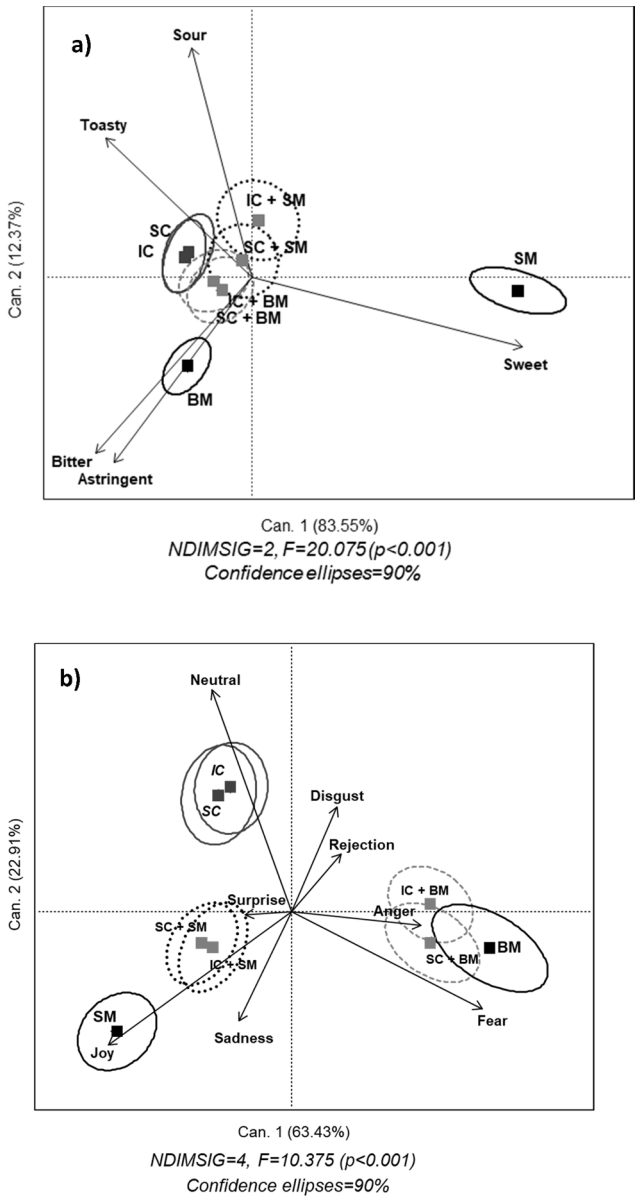


Fig. 8. a) Duration of dominance of flavor descriptors in music fragments, coffee and coffee tasted with music. b) Duration of dominance of emotions describing musical fragments, coffee and coffee tasted with music.

samples, and are described as *neutral*. In addition, "sweet" music was mostly described with *joy*, but tasting coffee also added a period of some *sadness*, together with *surprise*. In the case of "bitter" music, described mainly with *fear*, when tasting coffee some dominance of *anger* was added. In TDS the impact of music is smaller and the description of the coffees with music is closer to that of coffee itself rather than to the musical fragment. On the other hand, on TDE, the emotions are more associated to the music than to the product evaluated by itself. In this way, both music and taste contribute to the variety and complexity to the emotionality of the multisensory coffee experience.

There is extensive evidence supporting the hypothesis of "sensation transference" (Wang, 2017), that refers to the carrying over of the feelings about one stimulus to a different one experienced at the same time. This is possibly one of the mechanisms behind the effect of "sonic seasoning" found in this experiment.

In view of the above remarks, it seems relevant, in the present context, to distinguish between "sensorial transference" and "emotion transference" (Spence & Gallace, 2011; Spence, 2020) from the music stimulus. The latter effect appears much more important and clearer, while in contrast, from a sensory point of view, the driving stimulus appears to be coffee taste, and music only modulates taste perception to a limited extent. Importantly, however, it does so in a congruent way: "sweet" music increases the duration of dominance of *sweet* taste and reduces the duration of *bitter* in both coffees while "bitter" music enhances the duration of dominance of *bitter* taste (Fig. 4, Table 1). So, our results provide evidence consistent with the hypothesis of crossmodal sensorial and emotional transfer from music to coffee, adding to the results on juices, beer, chocolate and wine referred to in the introduction.

Working with chocolate, Reinoso-Carvalho, Gunn, Molina, et al. (2020) and Reinoso-Carvalho, Gunn, ter Horst, et al. (2020) also showed that "sonic seasoning" and sonic sensation transference could be combined and triggered concurrently, but that emotional influences were numerically larger than those reported for the sonic seasoning tracks. Ultimately, one of the aims of sonic seasoning research is to pick, or select, music combining elements carrying crossmodal flavor associations to enhance the desirable taste qualities, and capable also of enabling "emotional sonic sensation transfer" to enhance the overall multisensory experience (Spence, 2021).

5. Conclusion

Temporal dominance of sensations and emotions were efficient tools for describing and comparing the impact of music on the perceived taste and self-reported emotions during the coffee drinking experience.

The specific musical fragments had a significant effect in changing the flavor temporal perception of coffee, demonstrating that "sonic seasoning" can be achieved also with such a frequently consumed beverage. The obtained results show a promising use of music and auditory stimuli applied to, for example, reducing sugar intake. This could be of interest in contexts where people tend to over ingest sweeteners due to a significant coffee intake, such as office workers or university students.

Sensation transference from the music to the tasted coffee was observed, emphasizing that, in addition to the impact on taste, music can drive emotions and, in this way, define the tasting experience. This is also of great importance when generating an environment for coffee consumption, for using music for enhancing the uplifting boost of a coffee cup in the morning (perhaps using special "gastrosonic" devices such as the sonic glass described in Mesz et al., 2017) or creating atmospheres for more hedonic and refined coffee experiences.

More generally, our results indicate the importance of having a controlled sonic environment for performing sensory analysis studies and the significance of ambient sound for food consumption in restaurants, bars and cafeterias.

CRediT authorship contribution statement

M.V. Galmarini: Conceptualization, Methodology, Software, Formal analysis, Investigation, Resources, Visualization, Supervision, Writing – review & editing. **R.J. Silva Paz:** Investigation, Resources. **D. Enciso Choquehuanca:** Investigation, Resources. **M.C. Zamora:** Writing – review & editing. **B. Mesz:** Conceptualization, Methodology, Software, Formal analysis, Investigation, Resources, Visualization, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodres.2021.110795.

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