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DOES MUSIC INFLUENCE THE MULTISENSORY TASTING EXPERIENCE?

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ABSTRACT

All of the senses can potentially contribute to the perception and experience of food and drink. Sensory influences come both from the food or drink itself, and from the environment in which that food or drink is tasted and consumed. In this study, participants initially had to pair each of three soundtracks with one of three chocolates (varying on the bitter-sweet dimension). In a second part of the study, the impact of the various music samples on these participants' ratings of the taste of various chocolates was assessed. The results demonstrate that what people hear exerts a significant influence over their rating of the taste of the chocolate. Interestingly, when the results were analysed based on the participants' individual music-chocolate matches (rather than the average response of the whole group), more robust crossmodal effects were revealed. These results therefore provide support for the claim that ambient sound influences taste judgments, and potentially provide useful insights concerning the future design of multisensory tasting experiences.

PRACTICAL APPLICATIONS

The approach outlined here follows the increasing demand from the field of gastronomy for greater influence over the general multisensory atmosphere surrounding eating/drinking experiences. One of the novel contributions of the present research is to show how, by considering a participant's individual response, further insight for user-studies in gastrophysics may be provided. Increasing the personalization of such experiments in the years to come may help researchers to design individualized "sonic seasoning" experiences that are even more effective. In the future, then, the approach outlined here may help researchers and experience designers to obtain more profound effects of the auditory or multisensory atmosphere.

INTRODUCTION

The sound and/or noise in those places where we eat and drink, such as restaurants and airplanes, can dramatically affect our perception of taste and flavor (see Spence 2012; Spence *et al.* 2014, for reviews). Several acoustic parameters that can be used to define the auditory quality of a space, such as the reverberation time of a room and the level of background noise (Astolfi and Filippi 2004; Heylighen *et al.* 2009), have been shown to affect the tasting experience, as well as to alter the perception of different food attributes, such as, e.g., sweetness (e.g., Ferber and Cabanac 1987; Woods *et al.* 2011; Stafford *et al.* 2012; see Spence 2014, for a review of the influence of noise on the perception of food and drink).

Recent studies have highlighted the multisensory nature of taste/flavor perception, and several different methods with which to study the effect of what we hear on what we taste have been proposed (see Spence and Shankar 2010 and Knöferle and Spence 2012 for reviews). Here, though, it is important to distinguish between those sounds that are made by the food itself when being consumed (see Spence, 2015, for a review on the sounds of consumption) and other, unrelated, sounds (or music) that may also influence taste/flavor perception. The research reported here focuses on the effect that sounds that are unrelated to the food itself can nevertheless still exert over people's taste perception. These latter crossmodal effects are particularly intriguing as it is not immediately obvious how, or even why, what we hear should influence what we taste, in those cases where the inputs from the various senses share nothing in common.

Intriguing recent research has isolated a number of specific sonic and musical parameters (such as pitch and instrumentation) that can be used to modify tasting experiences (e.g., Bronner *et al.* 2012; Crisinel and Spence 2009, 2010, 2012; Crisinel *et al.* 2012). Of particular interest here, Crisinel and her coworkers have demonstrated that people's perception of the sweetness and bitterness in a bitter-sweet cinder toffee can be modulated using customized soundscapes. These soundscapes were designed, based on prior research, to be associated with sweetness or bitterness (see Crisinel *et al.* 2012 for details).

Here, we were motivated by the belief that it might be possible to propose novel ways in which to merge theoretical insights with the more personalized design of multisensory tasting experiences in the future. For example, one question that has been raised by previous research in this area is: What would happen should people be given the option of choosing the soundtrack that fits (or corresponds) with each taste? And would this allow us to gain a more nuanced understanding of the results?

Two underlying hypotheses guided the present research: The first part of the experiment (what will be referred to henceforth as the pretest) was designed to assess whether participants would match each of the three newly created soundtracks with the putatively matching taste. In the second part of the study, we then went on to assess whether listening to each of these three soundtracks would modulate the taste of the chocolates. The participants in the present study were given bitter, medium, and sweet chocolate to try. Based on prior research in this area, a soundtrack was composed to match each of the tastes. We then considered questions such as: Will a sweet chocolate taste sweeter while listening to music that itself has been composed to connote "sweetness"? And will listening to a bitter soundtrack make the chocolate seem less sweet?

METHODS

Participants

Twenty-four participants (12 females and 12 males; mean age: 22.7 years, SD 5.9) gave their informed consent to take part in the study. They reported that they did not have a cold nor any other known impairment of their sense of smell, taste, or hearing at the time of the study. The participants were informed that they would be tasting chocolate and listening to several different pieces of music. The experiment lasted for around 40 min. As compensation, two of the 24 participants had the chance to win a €15 gift voucher. The experiment was approved by the Ethics Committee of the Faculty of Arts and Philosophy of Ghent University.

Stimuli

Taste Stimuli. Three types of chocolate were used in this study, namely bitter chocolate (BC), medium chocolate (MC) and sweet chocolate (SC). The samples were prepared at The Chocolate Line factory in Bruges, under the supervision of the award-wining Belgian chocolatier Dominique Persoone (www.thechocolateline.be; see Table 1 for a description of the composition of the chocolates).

During production, there was a focus on the homogeneity of the samples, both in terms of their taste/flavor and their visual appearance, to reduce natural variation within the samples, given the artisanal nature of the products that they would taste. The participants tasted several chocolates during the course of the study, and each chocolate sample had the same small circular design, approximately 1 cm in diameter. Even though we attempted to produce all of the samples with an identical visual appearance, during the experiment, the shape and color of the chocolates could not be seen by the participants.

Auditory Stimuli. The soundtracks were produced in collaboration with the IPEM, Dept. of Musicology, at Ghent

TABLE 1. DESCRIPTION OF THE COMPOSITION OF THE CHOCOLATE SAMPLES USED IN THE PRESENT STUDY

Ingredients	BC	MC	SC
Sugar	34.4%	35.6%	43.7%
Cocoa butter	8.7%	22.4%	24.5%
Whole milk powder	–	20.0%	24.1%
Cocoa mass	56.9%	22.0%	7.2%
Soy lecithin	–	–	0.5%
Flavoring	Natural vanilla	Natural vanilla	Natural vanilla

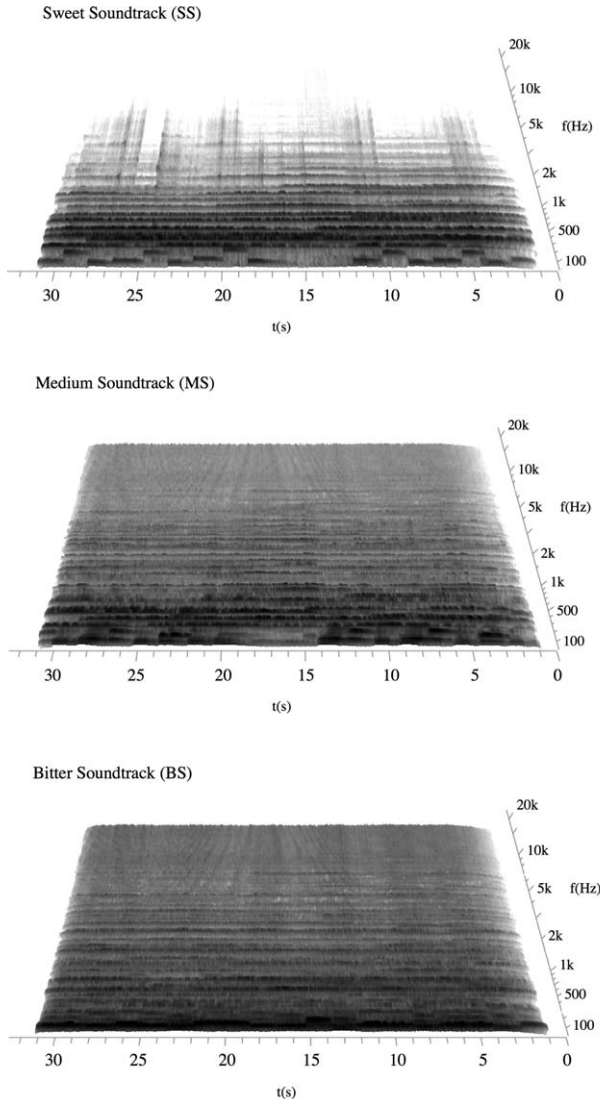

FIG. 1. SPECTRAL AND TEMPORAL FEATURES OF SWEET SOUNDTRACK (SS), MEDIUM SOUNDTRACK (MS), AND BITTER SOUNDTRACK (BS) – 3D SPECTROGRAM
At low frequencies, BS has constant energy whereas SS and MS have more of an itinerant behavior. At midhigh frequency ranges, there are more similarities between MS and BS, rather than between MS and SS. [Source: Izotope Ozone]

University. They were created using Steinberg Cubase and Pure Data. Each soundtrack was produced on the basis of the previously mentioned literature to be congruent with each of the three chocolate samples. The composition process was based on a discussion between the main composer, a sound designer, a musicologist and a philosopher. Knoferle and Spence's (2012) summary of the crossmodal correspondences between basic tastes and sonic elements acted as the main inspiration for the present study, along with the music samples produced for Crisinel *et al.*'s (2012) experiment. Thereafter, baseline cues such as: high-pitched "bubbling" sounds for sweetness; low resonance filters for bitterness; and a narrowed frequency bandwidth for the medium soundtrack, were defined.

All of the sounds were presented in the key of D. The "bitter" soundtrack (referred to as BS, which was intended to be congruent with the BC) consisted of complex overtones, low resonance filters, and static pulses as the result of a saw tooth wave function.[1] The most prominent sound was a note pitched at F4 with an open fifth changing bass pattern. The "sweet" soundtrack (referred as SS) was designed to be congruent with the SC – and involved high resonant filters with round-bubbling sounds. The sounds were more continuous than for the BS and had a smooth continuous chord of D4 sounding reminiscent of a synthesizer with complex overtones, consisting of inverse effects on the chord of F6. The baseline of the medium soundtrack (referred to as MS and intended to be congruent with the MC) consisted of the combination of a new baseline produced as neutral, mixed with the BS (the mix preserved a difference of 10 dB between the two samples, with the neutral baseline on top). With a narrowed frequency bandwidth and an open third on D4 (without F4), this baseline is, theoretically, the least significant of the three.

Figure 1 shows the spectral and temporal features of the three soundtracks. The soundtracks were further equalized in terms of their loudness. For the mastering process, the software Pro Tools 10 along with a Waves Platinum plug-in bundle was used. In general, the BS had more energy at lower frequencies whereas the SS had more energy at mid-to-high frequencies. Each soundtrack was approximately 35 s in duration. The music samples can be heard at chocolatetriad.tumblr.com.

Initially, a control study was conducted to check that naïve listeners would indeed associate each of the soundtracks as intended. One hundred and ten people were individually invited to take part in an on-line survey (mean age:

[1]The terminology used in this part of the text corresponds to music composition methods based on audio synthesis. Therefore, concepts such as "saw tooth wave function" or "complex overtones" may sound unfamiliar to musicians who compose using traditional musical notation.

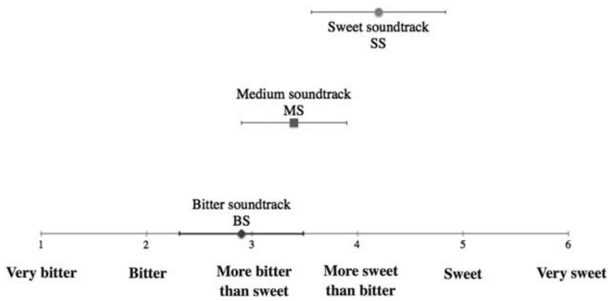

FIG. 2. MEAN RATINGS (AND STANDARD ERROR) OF THE THREE SOUNDTRACKS ON THE SWEET-BITTER SCALE
Overall, the 110 participants evaluated SS as sweeter than either of the other two soundtracks. Furthermore, BS was evaluated as the bitterest sound by the majority of participants. The graph also shows the scale labels used during the experiment.

30.4 years, SD 7.5). Through an on-line questionnaire, they had to input their name, age, and email address. It was not possible to enter the same name nor email address on more than one occasion. Each participant gave their informed consent, reporting no hearing or visual impairment. The participants were told that they would have to rank three soundtracks on a 6-point bitter-sweet Likert-scale (see Fig. 2). The participants were advised to compare their rankings of the soundtracks before submitting their final judgment. They were also advised to use headphones, or at least a pair of speakers, to be able to complete the study. The survey lasted for approximately 5 min and, with the objective of attracting as many participants as possible, the questionnaire was presented as a quiz. At the end of the quiz, each participant could access their own individual results and read the debriefing text, which contained information about the purpose of the study. As compensation, the participants had the chance to win a €20 gift voucher. Figure 2 shows that the participants' evaluation of the musical selections was as anticipated, with SS rated as the sweetest, BS the most bitter and MS falling in-between. The difference between the ratings of the 3 soundtracks was significant (all pairwise comparisons $<= 0.001$).

Procedure

The experiment took place in a darkened experimental room at IPEM. Before entering, the participants completed a pre-questionnaire to collect personal data and the general consent. Three participants entered the experimental area at one time. There was one supervisor per participant during the experiment. Three small booths were set up, separated by black curtains to prevent communication between the participants.

Each sound reproduction system was calibrated by a CESVA SC310 sonometer to ensure that the participants all heard the soundtracks at exactly the same sound pressure level (73 dBA $\pm$ 2 dB). The soundtracks were presented over Sennheiser HD 215 headphones. The participants were seated in front of a computer screen, mirrored with the computer of the supervisor on the other side of the table. The three soundtracks were presented separately on the screen using an Internet browser. A small LED-light was installed next to each participant for them to be able to fill in their questionnaire. Each soundtrack was labeled with a letter (X, Y, or Z) and each chocolate was labeled with a numerical code (1, 2, or 3). However, only the supervisor knew which label corresponded to which soundtrack/chocolate. The only information that the participants had concerning the soundtracks and chocolates were letters and numbers, respectively.

The experiment was subdivided into three parts: introduction, pretest, and test. All three parts were performed while the participants were inside the individual booths. During the introduction to the experiment, the participants were acquainted with the range of chocolates and auditory stimuli that would be used during the main part of the experiment. The supervisor gave the participant a sample of each of the three chocolates without any soundtrack. After tasting, the participant could listen to each soundtrack over headphones by clicking on the computer screen using a PC mouse. The objective of this part of the study was to present the various flavors and sounds to make the participants feel comfortable.

In the pretest, the participants had to match a chocolate sample with a soundtrack. Each participant was given six chocolates (2 bitter, 2 medium, and 2 sweet) and the three soundtracks to listen to. They were given approximately 5 min in which to evaluate the various chocolate-soundtrack combinations. They could listen to the soundtracks for as long as necessary, limited only by the number of chocolate samples that had to be tasted. In the questionnaires, the participants reported their preferred combination of chocolate/soundtrack. Each combination had to be rated on a 5-point Likert-scale ranging from "very bad," "bad," "normal," "good," to "very good." The participants were informed that it was not possible to choose the same soundtrack for two different types of chocolate.

For the test, the chocolates and soundtracks were presented in pairs. The objective was to study the influence of the soundtrack (as compared to silence) on participants' taste ratings. In total, nine pairs of stimuli were presented to participants, with each pair of stimuli being presented in a random order. Each time a chocolate was tasted, the participants had to rate their experience.

For each possible chocolate/soundtrack combination, there were two 9-point Likert scales. One scale was for the evaluation of the chocolate in silence and the other was for evaluating the chocolate while listening to a soundtrack (the order of evaluation, eating the chocolate first in silence or

TABLE 2. MATRIX SHOWING HOW THE PARTICIPANTS MATCHED A CHOCOLATE SAMPLE WITH A SOUNDTRACK (CHOCOLATE IN COLUMNS, SOUNDTRACKS IN ROWS)

Chocolate\Soundtrack	BC	MC	SC
BS	**20 (83.3%)**	3 (12.5%)	1 (4.2%)
MS	3 (12.5%)	9 (37.5%)	**12 (50.0%)**
SS	1 (4.2%)	**12 (50.0%)**	11 (45.8%)

The bold/underline entries highlight the most common match between each music and chocolate sample. 50% of all participants paired the SC with the MS, while 50% reported that the best combination for the MC was, in fact, the SS.

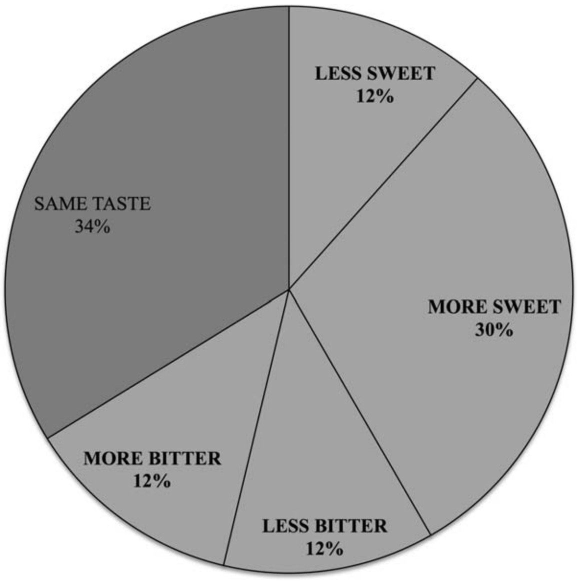

FIG. 3. THE MOST FREQUENT CHANGE IN TASTE PERCEPTION REPORTED WHILE LISTENING TO ONE OF THE SOUNDTRACKS WAS AN INCREASE IN SWEETNESS (APPROXIMATELY 30%)
In only 12% of the ratings, was a change in perception toward bitterness reported. In approximately 34% of cases, no discernible change in taste was reported.

first while listening to the soundtrack, was randomized for all of the participants). The scales went from very bitter (−4), passing through neutral (0), to very sweet (4). To help the participants maintain their attention on task and answer correctly, an additional third question was posed, requiring them to compare the two previous ratings.[2] This rating consisted of two options on 5-point Likert scales. One went from less sweet (−2), passing through same taste (0), toward more sweet (2), and the other from less bitter (−2), passing through same taste (0) toward more bitter (2). Regarding the third question, the participants were advised to choose just one scale, depending on whether their focus at the time was on the perception of bitterness or sweetness.

[2]Due to the redundancy of data, it was decided not to discuss the answers of these third question in the results.

TABLE 3. MEANS AND SD OF THE RATINGS OF THE CHOCOLATES, BASED ON THE ANSWERS OF THE 9-POINT LIKERT SCALES, WHERE THE PARTICIPANTS RATED THE CHOCOLATE'S TASTE IN SILENCE

	Mean	Standard deviation (SD)
BC	−2.58	0.9
MC	1.15	1.5
SC	2.36	1.2

Note that the differences between the SC/MC means are 1.2 points, whereas the differences between the MC/BC and the SC/BC means are of 3.7 and 4.9 points, respectively. Here we can also mention that the SD for the MC/SC are 40% and 25% wider, respectively, when compared to the SD of the BC, from this it might be concluded that the participants had a more consistent agreement regarding the ratings of the BC's taste.

On finishing the experiment, the participants were instructed to leave the room without discussing any details with the next group of participants. Tap water and white bread to neutralize the taste of the preceding chocolate were available during the whole experimental procedure.

RESULTS

The pretest assessed the soundtrack that the participants chose as fitting, or corresponding, with the taste of each chocolate (see Table 2). The majority of the participants (approximately 83%) matched the BC with the BS rather than with the other soundtracks. Most participants preferred either the SS or MS with the sweet and MCs. 48% of the participants rated the combinations as "very good" and 29% as "good." Only 4% of the combinations were rated as "bad."

The test assessed whether the soundtracks that were produced specifically for this experiment would modulate the perceived taste of the chocolates, potentially making them taste more or less bitter/sweet. The following results report the modulatory influence of the three soundtracks on the taste of each category of chocolate. Here we analyzed the answers of the two 9-point Likert scales, where the participants compared the taste of the chocolate in silence versus while listening to a soundtrack. Figure 3 shows an overview of these ratings.

Note that the participants evaluated the same chocolate in silence more than once (see Table 3 for means and SD of such ratings), and hence analyzing these responses allowed us to get a sense of the consistency of their taste ratings. We considered "consistent" as rating with a difference in the Likert-scale of no more than 2 points. Anything outside of these limits was considered inconsistent. Approximately 87% of the BC ratings, 80% of the SC ratings, and 75% of the MC ratings were consistent. It is worth noting that the MC would presumably have been more likely to be subject

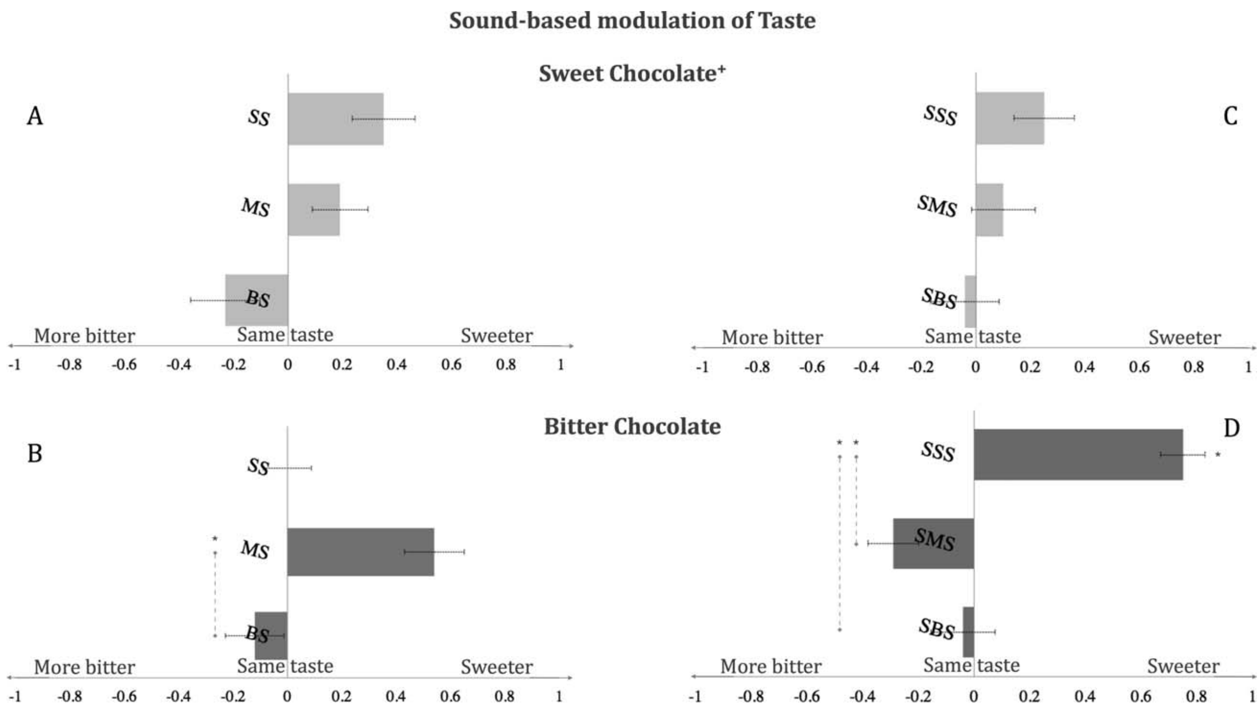

FIG. 4. SOUND-BASED MODULATION OF TASTE FOR THE SWEET+ AND BITTER CHOCOLATES – CONSIDERING THE THREE SOUNDTRACKS
Panels A and B follow the chocolate/soundtrack pairing found in the group average. In C and D, the data were reorganized based on the pretest results, in which the participants made their own pairs. Thus, in A and B the soundtracks are always the same for each chocolate, for every participant. In C and D what the theoretical baseline predefined as a sweet soundtrack could be sweet, medium or even bitter, depending on the participant. The asterisks highlight a significant difference between the conditions ($P < 0.05$). All resultant means fall between "−1" and "1." Therefore, for a better visualization, the scale of the figure's axis has been limited.

to order effects (since it has been argued that crossmodal correspondences are typically relative, rather than absolute, i.e., it is the sweeter chocolate that is matched with the higher pitched music – Gallace and Spence, 2006; Spence 2011). As the order of presentation of the chocolates was randomized, the chocolate that was tasted immediately beforehand could potentially have influenced ratings related to MC. In other words, MC could be "relatively sweeter" after tasting BC, but "relatively more bitter" after a SC. To assess any such potential order effects, the ratings corresponding to the MC were reclassified considering the taste stimuli on preceding trial (if MC was consumed after a BC or after a SC).[3] This analysis of order effects in the data revealed that the MC might, indeed, be subject to order effects.

[3]The mean of each condition was obtained, for each soundtrack. The mean of the MC/BS consumed after a BC is one point higher than the mean when MC/BS was consumed after a SC. The mean of the MC/SS consumed after a BC is 0.8 points higher than the mean when MC/SS was consumed after a SC. Finally, the mean of the MC/MS consumed after a BC is 0.2 points higher than the mean when MC/MS was consumed after a SC.

Having the previous results and analysis in mind, it was decided to consider two new aspects in our data analysis. First, the preliminary analysis of the data revealed that the participants were not able to distinguish clearly between the sweet and medium chocolates. Therefore, we decided to collapse the SC and MC into a single category next to the BC, namely sweet chocolate^{+} (SC^{+}). Second, we wanted to assess whether the crossmodal matches that had been made by each individual in the pretest would predict, in the test, better than the average response from the whole group. Note that such an individual-correspondence based analysis has not been attempted previously. This reorganization of soundtracks will be referred as "subject-matched soundtracks," such as subject sweet soundtrack (SSS) and so on.

Figure 4 illustrates how the perception of the taste of the chocolate was influenced by listening to a soundtrack versus when tasting in silence. Zero corresponds to "no change in taste" (same taste). Positive values (to the right) indicate that the participants reported that the sweetness of the chocolate was enhanced while listening to a soundtrack. Negative values (to the left) indicate that the participants rated the chocolate as tasting more bitter while listening to a given soundtrack.

The expected effects of each soundtrack are clearly represented in the modulation of the taste of the sweet chocolate^{+} (see Fig. 4). Furthermore, by comparing the individual-pairing choices with the group averages, we were able to highlight one case in which the modulation effects of the soundtracks on taste went in opposite directions. When considering the group average approach, we see an increase in sweetness (MS/BC, panel B), whereas when considering the individually-matched one, a trend toward increased bitterness can be seen (SMS/BC, panel D).

To assess the significance of the results, the data presented in Fig. 4 was submitted to a repeated measures analysis of variance with Bonferroni correction for multiple comparisons ($P < .05$). From the taste comparisons showed in Fig. 4, note that four achieved statistical significance. The first was achieved while the participants were comparing the taste of the BC when listening to the SSS, versus tasting in silence. The other three referred to the comparisons among the modulation trends visualized in each panel of Fig. 4 (BC-BS/BC-MS; BC-SBS/BC-SSS; BC-SMS/BC-SSS). That being said, we can presume that it is feasible to achieve further significant differences between the conditions if a comparison of taste is made while listening to two different soundtracks, i.e., soundtracks that are meant to have opposite effects on taste, rather than comparing taste while listening to a soundtrack versus when tasting in silence.

From the statistical analysis of the results, it is possible to see, first, that all of the significant results relate to the BC sample. Second, three out of the four significant terms relate to the data that deal with the participants' individual pairings.

DISCUSSION

The results of the pretest reported in this study show that the participants made the expected association between BC-BS, whereas the associations between MC-MS and SC-SS were not so clear. The results suggested that the MS and SS were equally likely to be associated with either SC or MC. It is certainly possible that the BC – with 70% cacao – may have demanded less effort to distinguish because of the lack of any milk supplements, as compared to the other two chocolate samples (see Table 1). Therefore, the MC could have been perceived by the majority of the participants as simply "less sweet than the sweet chocolate" – and not necessarily as a qualitatively different type of chocolate – and this may have caused a general distortion in participants' ratings (see Table 3).

It is also possible that the difference between the sweet and medium soundtracks (SS and MS) was not sufficiently clear to our participants. Yet, counteracting such a claim, the results of the control experiment demonstrated that the difference between SS and MS ratings was around 50% larger than the difference between MS and BS (see Fig. 2). Therefore, unlike the case involving sweet and MCs, we have clear evidence that the participants should not have experienced any difficulties in distinguishing the sweet soundtrack from the medium one.

The results of the test confirm that it is possible to significantly influence taste using sonic cues that are unrelated to the food itself. Moreover, by letting the participants match their own stimuli, it was possible to achieve more significant differences between the conditions presented. From this, it can be assumed that this intervention allowed for the disclosure of more robust crossmodal effects. Therefore, the crossmodal correspondences that had been made by each individual in the first part of the study helped us to predict their responses better than the group average.

Working with three different varieties of the same type of food helped interpret the information collected in the present study. We were able to point out two specific cases where the discussion regarding the efficiency of this type of method can be enriched. First, we detected that crossmodal correspondences may become relative due to order effects. Second, when working among different varieties of the same food sample, it is clear that there should be a concern related to the ability of the participants to distinguish between different tastes.

New methods, such as those proposed here, reflect the increasing demand from the growing research interest in gastrophysics – specifically for ways to exert more influence over both, the individual experience and the general atmosphere surrounding tasting experiences. Here, we demonstrate that it is possible to design soundscapes that can enhance the taste of food. Furthermore, our results also show that such soundtracks can even be submitted to a personalization process and still be effective. That being said, sound design with gastrophysics in mind can be effective for group experiences and, as we show, even more effective for those experiences that are designed on an individual basis. Sonic-seasoning methods may further blend with visual ones, such as demonstrated in a recent experiment (Spence *et al.* 2014), in which more than 3,000 participants tasted wine under different combinations of customized lightening and soundscaping. As attentional control may also play a key role in multisensory experiences [underlined by the finding that attention can be captured using specific temporally congruent stimuli (Van Ee *et al.* 2009)], approaches that can help to focus the attention of the individual observers will also become relevant. Heston Blumenthal, with his "Sound of the Sea" (Blumenthal, 2008), and Massimo Bottura's "Tribute to Thelonious Monk" (Bottura, 2014), can be mentioned as but two examples of chefs who have looked for inspiration in sound and music while conceiving their gastronomic creations as well. Here, it is worth mentioning that Heston Blumenthal's "Sound of the Sea" is an experience that is delivered individually to each diner. Specifically, the customer eats while listening to an individual soundscape over headphones. Thus, we would argue that there is space in at least certain restaurants for individualized multisensory tasting experiences. And since virtual environments are also becoming a more frequent part of our daily lives, individual multisensory tasting experiences should also become more accessible, and more desirable.

Finally, this study shows that people's rating of the taste of food can be significantly modulated by means of predefined sonic cues. These results also reveal that it is possible to add a participatory layer into the experience without losing control of the expected effect regarding crossmodal correspondences. Furthermore, we also present further support for the claim that crossmodal correspondences may be relative. A deeper study of personalization in similar future experiments may help to obtain additional precision in the future design of more complex and pragmatic experiences.

CONCLUSION

The influence of certain specific soundtracks on consumers' taste perception was studied. The participants evaluated the relationship between customized sonic cues and the taste of different types of chocolate. Part of this evaluation validates existing theoretical accounts regarding the existence of crossmodal correspondences between sound and taste. However, our results go beyond the current state of the art by demonstrating that people's taste can be influenced by sound to an even greater extent, when the sounds are reclassified by the participant's own personal responses. Such results, then, provide further support for the claim that crossmodal correspondences between taste/flavor and music can influence the ratings of those engaged in participatory experiences. Future research in gastrophysics that takes into account the participants' individual crossmodal matches, may well obtain more robust effects than those seen when using averaged group data.

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REFERENCES

ASTOLFI, A. and FILIPPI, M. 2004. Good acoustical quality in restaurants: A compromise between speech intelligibility and privacy. Proceedings 18th International Congress on Acoustics ICA 2004, pp. 1201–1204, Kyoto, Japan.

BLUMENTHAL, H. 2008. *The Big Fat Duck Cookbook*, Bloomsbury, London, UK.

BOTTURA, M. 2014. *Never Trust a Skinny Italian Chef*, Phaidon, London, UK.

BRONNER, K., BRUHN, H., HIRT, R. and PIPER, D. 2012. What is the sound of citrus? Research on the correspondences between the perception of sound and flavour. Proceedings of the 12th International Conference of Music Perception and Cognition (ICMPC) and the 8th Triennial Conference of the European Society for the Cognitive Sciences of Music (ESCOM) 2012, pp. 142–148, Thessaloniki, Greece.

CRISINEL, A.-S., COSSER, S., KING, S., JONES, R., PETRIE, J. and SPENCE, C. 2012. A bittersweet symphony: Systematically modulating the taste of food by changing the sonic properties of the soundtrack playing in the background. Food Qual. Prefer. *24*(1), 201–204.

CRISINEL, A.-S. and SPENCE, S. 2009. Implicit association between basic tastes and pitch. Neurosci. Lett. *464*(1), 39–42.

CRISINEL, A.-S. and SPENCE, C. 2010. As bitter as a trombone: Synesthetic correspondences in non-synesthetes between tastes and flavors and musical instruments and notes. Atten. Percept. Psychophys. *72*(7), 1994–2002.

CRISINEL, A.-S. and SPENCE, C. 2012. The impact of pleasantness ratings on crossmodal associations between food samples and musical notes. Food Qual. Prefer. *24*(1), 136–140.

FERBER, C. and CABANAC, M. 1987. Influence of noise on gustatory affective ratings and preference for sweet or salt. Appetite *8*(3), 229–235.

GALLACE, A. and SPENCE, C. 2006. Multisensory synesthetic interactions in the speeded classification of visual size. Percept. Psychophys. *68*, 1191–1203.

HEYLIGHEN, A., RYCHTÁRIKOVÁ, M. and VERMEIR, G. 2009. Designing spaces for every listener. Univers. Access Inf. Soc. *9*(3), 283–292.

KNÖFERLE, K. and SPENCE, C. 2012. Crossmodal correspondences between sounds and tastes. Psychon. Bull. Rev. *19*(6), 992–1006.

SPENCE, C. 2011. Crossmodal correspondences: A tutorial review. Atten. Percept. Psychophys. *73*(4), 971–995.

SPENCE, C. 2012. Auditory contributions to flavour perception and feeding behaviour. Physiol. Behav. *107*(4), 505–515.

SPENCE, C. 2014. Noise and its impact on the perception of food and drink. Flavour *3*, 9.

SPENCE, C. 2015. Eating with our ears: Assessing the importance of the sounds of consumption to our perception and enjoyment of multisensory flavour experiences. Flavour *4*, 3.

SPENCE, C., MICHEL, C. and SMITH, B. 2014. Airplane noise and the taste of umami. Flavour *3*, 2.

SPENCE, C. and SHANKAR, M.U. 2010. The influence of auditory cues on the perception of, and responses to, food and drink. J. Sens. Stud. *25*(3), 406–430.

SPENCE, C., VELASCO, C. and KNOEFERLE, K. 2014. A large sample study on the influence of the multisensory environment on the wine drinking experience. Flavour *3*(1), 8.

STAFFORD, L.D., FERNANDES, M. and AGOBIANI, E. 2012. Effects of noise and distraction on alcohol perception. Food Qual. Prefer. *24*(1), 218–224.

VAN EE, R., VAN BOXTEL, J.J.A., PARKER, A.L. and ALAIS, D. 2009. Multisensory congruency as a mechanism for attentional control over perceptual selection. J. Neurosci. *29*(37), 11641–11649.

WOODS, A.T., POLIAKOFF, E., LLOYD, D.M., KUENZEL, J., HODSON, R., GONDA, H., BATCHELOR, J., DIJKSTERHUIS, A. and THOMAS, A. 2011. Effect of background noise on food perception. Food Qual. Prefer. *22*(1), 42–47.