"Smooth Operator":
Music modulates the perceived creaminess,
sweetness, and bitterness of chocolate

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Abstract

There has been a recent growth of interest in determining whether sound (specifically music and soundscapes) can enhance not only the basic taste attributes associated with food and beverage items (such as sweetness, bitterness, sourness, etc.), but also other important components of the tasting experience, such as, for instance, crunchiness, creaminess, and/or carbonation. In the present study, participants evaluated the perceived creaminess of chocolate. Two contrasting soundtracks were produced with such texture-correspondences in mind, and validated by means of a pre-test. The participants tasted the same chocolate twice (without knowing that the chocolates were identical), each time listening to one of the soundtracks. The 'creamy' soundtrack enhanced the perceived creaminess and sweetness of the chocolates, as compared to the ratings given while listening to the 'rough' soundtrack. Moreover, while the participants preferred the creamy soundtrack, this difference did not appear to affect their overall enjoyment of the chocolates. Interestingly, and in contrast with previous similar studies, these results demonstrate that in certain cases, sounds can have a perceptual effect on gustatory food attributes without necessarily altering the hedonic experience.

Keywords: *taste, sound, music, chocolate, crossmodal correspondences, multisensory perception.*

1. Introduction

The sound and/or noise in those places where we eat and drink - such as restaurants and bars - can affect our perception of taste and flavor (see Spence, 2012; Stafford et al, 2012; Spence, Michel, & Smith, 2014, for reviews). Furthermore, chefs and a number of other food industry professionals have recently become increasingly interested in the latest scientific findings regarding multisensory flavor perception. As such, a number of them are starting to use such insights in order to progressively innovate the design of the multisensory dining experiences that they develop (see Spence, 2015b, for a review). Studies assessing the influence of the sound of the food itself have revealed that this can add significant value to people's experience of food and drink (e.g., Knight, 2012; Spence & Shankar, 2010; see Spence, 2015a, and Knöferle & Spence, 2012, for reviews). However, it is important to distinguish here between those sounds that are made by the food itself when masticated/consumed (see Spence, 2015a, for a review on the sounds of consumption) and other unrelated sounds and music that may also influence taste/flavor perception.

The research reported here focuses on how sounds that are unrelated to the food itself can nevertheless still influence people's taste/flavor perception. For instance, recent studies have isolated a number of specific sonic and musical parameters (such as pitch and instrumentation) that can be used to modify tasting experiences, thus potentially adding significant value and pleasure to the consumer's overall eating/drinking experience (e.g., Bronner et al., 2012; Crisinel et al., 2012; Reinoso Carvalho, 2013, 2015a-c, 2016; Wang & Spence, 2015a, 2015b, 2016). In particular, Reinoso Carvalho et al. (2015a, 2016), Wang and Spence (2016), and Crisinel et al. (2012) have all demonstrated that it is possible to compose soundscapes that systematically affect the perceived flavor of food and/or drinks. These studies used soundtracks that had been produced specifically for the purpose of modulating basic taste attributes of food, such as sweetness and/or bitterness (Reinoso Carvalho et al., 2015a; see Spence & Shankar, 2010; Knöferle & Spence, 2012, Knoeferle et al., 2015, for overviews). Recent research has also reported that the more a person likes a sound, the more pleasant they will perceive a subsequently-presented odor (Seo & Hummel, 2011). Moreover, the rated pleasantness of odors can increase in the presence of congruent sounds (Seo et al., 2014). Both of the aforementioned examples clearly have relevance to the assessment of food and drink, since flavor perception involves taste and smell (Spence & Piqueras-Fiszman, 2014). In addition, similar studies have focused on assessing how music tends to have an effect in the hedonic and perceptual ratings on tasting experiences, with sound potentially being able to enhance the general enjoyment of food and drinks (i.e., Spence et al., 2013; Kantono et al., 2015; Kantono et al., 2016; Reinoso Carvalho et al., 2015b). Here, sensation transference has been discussed as an active mechanism that may account for these effects. The aforementioned studies argue that the positive feelings that we associate with music end up being transferred towards the pleasure associated to the food or beverages in question (i.e., Reinoso Carvalho et al., 2016; see Cheskin, 1972, and Spence, 2016, for an overview of the literature on sensation transference).

As mentioned above, a spate of recent studies has questioned whether sound can enhance basic taste attributes (i.e., sweetness, bitterness, sourness, etc.). Moving forward, there is now a growing interest in determining whether sound can also influence people's perception of other flavor attributes as well (Spence, 2015a). For instance, can the presentation of appropriate sounds (that are not necessarily related to eating/drinking) make food/drinks appear more/less crispy, crunchy, creamy, and/or carbonated?

In the present study, we hypothesized that specific soundtracks might affect the perceived texture of chocolate, in particular its creaminess. Here, it is important to mention that previous similar research has assessed the various different ways in which the perceived texture of food can be associated – and potentially altered – by the different combinations of sensory stimuli. For instance, round shapes tend to be associated with creaminess (Yorkston & Menon, 2004). Furthermore, differences in the texture of a food's surface can also alter its perceived sourness (Slocombe, Carmichael, & Simner, 2016). Previous research has also demonstrated that sweeter chocolates are usually associated with rounder shapes, whereas more bitter chocolates are more commonly matched with angular shapes instead (Ngo, Misra & Spence, 2011; Gallace, Boschin, & Spence, 2011; see Spence & Deroy, 2012, and Bremner et al., 2013, for overviews).

In the experiment reported here, the participants tasted and rated the same chocolate twice (without knowing that the chocolates were identical), each time under the influence of one of two soundtracks. The soundtracks were produced to evoke either creaminess or roughness (in this case, roughness has being defined as the opposite of creaminess). The production of these soundtracks was based on the published empirical literature. First, the bouba-kiki effect (also known as the "maluma-takete" effect) was taken into consideration as a starting point. People tend to associate round/smooth visual/auditory cues with "bouba"-like words, whereas sharp/rough stimuli may be naturally associated with more "kiki"-like words (Köhler, 1929, and 1947; Bremner et al., 2013). With this in mind, one might associate purer waveforms with smoothness (bouba/maluma) and more complex waveforms with roughness (kiki/takete). Eitan and Rothschild (2010) also provided some potential musical guidance here. These researchers addressed musical parameters, such as pitch, loudness, timbre, and how they may affect auditory-tactile metaphorical mappings. They found, for example, that a flute's simpler sound wave was rated as smoother than the more complex sound of a violin.

2. Methods

2.1 Participants

116 participants (65 females and 51 males; mean age = 35.11 years, SD = 14.49) took part in the experiment, after giving their informed consent. They reported that they did not have a cold or 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 chocolates while sometimes listening to different pieces of music. The experiment lasted for approximately 10 minutes.

2.2 Stimuli

Taste Stimuli: In order to test the effect of the sound stimuli on different types of chocolates, two chocolate formulas were chosen for this study. While designing these chocolate samples, we realized that the only chocolate formulas that wouldn't have significant changes in color would be the ones that do not include milk. It was important for us to keep the color of the chocolate samples as similar as possible, so it would not influence participants' responses. Therefore, it was decided to use only cocoa-based formulas. However, prior the definitive choices of cocoa percentages, pilot studies were performed in order to determine which combination of cacao would be appropriate to use for the experiences. These pilots were developed along with professional chocolatiers, and included several different formulas. Finally, the chosen formulas had 71% and 80% cocoa content (both milk-free chocolate formulas, with the following basic ingredients: cocoa mass, sugar, cocoa butter and natural vanilla flavor). Moreover, each formula was presented in two different molds (see Figure 1, top). In total, four different chocolate types were available, one for each group of participants (see Figure 1, bottom). The chocolates were developed at The Chocolate Line factory in Bruges, under the supervision of the award-wining Belgian chocolatier Dominique Persoone (www.thechocolateline.be).

Note that all of the experimental chocolate samples had the same dark brown color, and similar volume (approximately 2.0 cm^3).

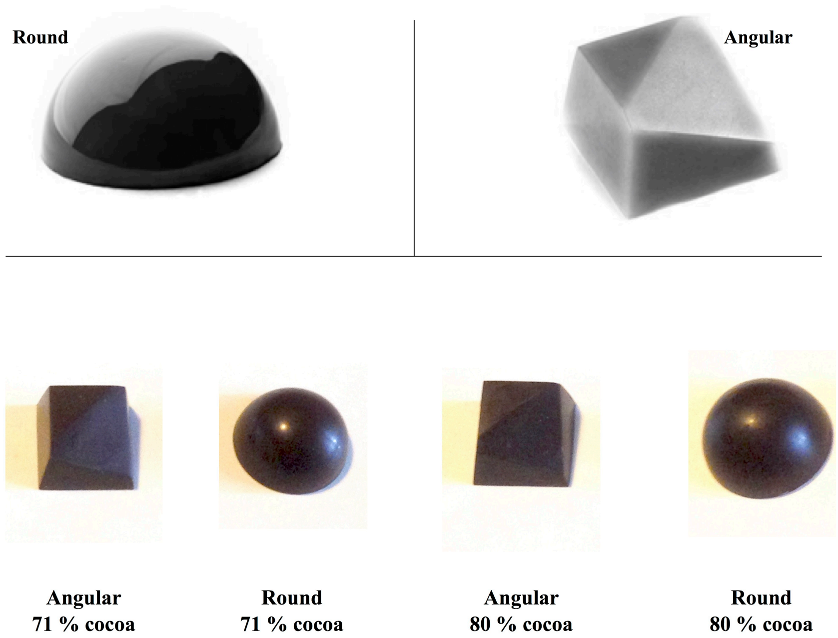

Figure 1. Round (top-left) and angular (top-right) shapes of the chocolates. Each group tasted one type of chocolate (bottom). All of them had the same color, and each shape was prepared with the 71%, and 80% cocoa chocolate formula.

Auditory stimuli: Two soundtracks were prepared for this experiment, one corresponding to smoothness/creaminess, and the other to roughness. Along with the bouba-kiki effect (Köhler, 1929, 1947), the relationship between touch and sound highlighted by Eitan and Rothschild (2010) acted as a starting point for the production of the soundtracks. We reasoned that soft/smooth sounds are usually correlated with long-consonant-legato notes. By contrast, hard/rough sounds are most likely represented by short-dissonant-staccato notes. For example, in Eitan and Rothschild's (2010) study, higher – and louder – pitches/notes were rated as rougher/harder. Moreover, the sound of the violin was rated as rougher/harder and drier as compared to the sound of the flute. That being said, the first soundtrack (produced to be congruent with creaminess, namely the ‘creamy soundtrack’) consisted of a loop-ascending scale of consonant-long flute notes, mixed with large hall reverberation. The second soundtrack (namely the ‘rough soundtrack’, was intended to have an opposite effect from creamy soundtrack) consisted of a loop-ascending scale of three blended dissonant-dry pizzicato short violin lines.

Both soundtracks had approximately the same pitch range, and both lasted for approximately 1 minute. They were mastered to have similar dynamics and loudness (Leq_{1min}= 70 +/- 3 dBA). Note that due to the fact that the rough soundtrack has three melodic lines playing together, with one of those melodies in a higher pitch, it is possible that this soundtrack may have been perceived as higher in pitch, when compared to the creamy soundtrack. The soundtracks can be accessed via the following link: http://tinyurl.com/creaminess-chocolate (retrieved in October, 2016).

Initially, a pre-test was conducted in order to verify that naïve listeners would indeed associate each of the soundtracks with the intended texture. Sixty-five people (36 female, 29 male; Mean age = 31.63 years, SD 16.46) took part in this pre-test. Here, the goal was to make the rating scales as comprehensive as possible for naïve listeners, in order to complete the task of evaluating soundtracks in terms of tasting attributes. First, we considered that sweetness and bitterness are usually opposites in terms of valence – as compared to, for example, sourness and bitterness (Reinoso Carvalho et al., 2016; Salgado-Montejo et al., 2015; Yarmolinsky et al., 2009). Second, due to the fact that the opposite of creaminess may have more than one interpretation (i.e., watery, rough, lumpy, etc.), we decided to narrow the options down to the roughness of a chocolate, when compared to its creaminess. That being said, in this pre-test, we decided to work with two bipolar dimensional scales, one creamy-rough, and another bitter-sweet. This decision was made with the intention of providing an objective way of evaluating two soundtracks that were produced to have opposite perceptual effects on the texture of chocolate.

Each participant listened to both soundtracks and rated them on a 7-point bitter-to-sweet scale (‘1’ = Very bitter, ‘4’ = Balanced, ‘7’ = Very sweet), and on a 7-point rough-to-creamy scale (‘1’ = Very rough, ‘4’ = Balanced, ‘7’ = Very creamy). A significant difference between the ratings of the soundtracks was reported (ANOVA, $F(2, 127) = .33.62$, $p < .005$, $\eta^2 = .35$). The results of the pre-test revealed that the creamy soundtrack was rated as significantly creamier (Mean creamy soundtrack = 4.95 SE = .17; Mean rough soundtrack = 3.00 SE = .17, $p < .005$) and sweeter (Mean creamy soundtrack = 4.49 SE = .17, Mean rough soundtrack = 3.20 SE = .17, $p < .005$), than the rough soundtrack. In summary, the participants were able to classify both soundtracks as expected. Figure 2 shows the aforementioned ratings.

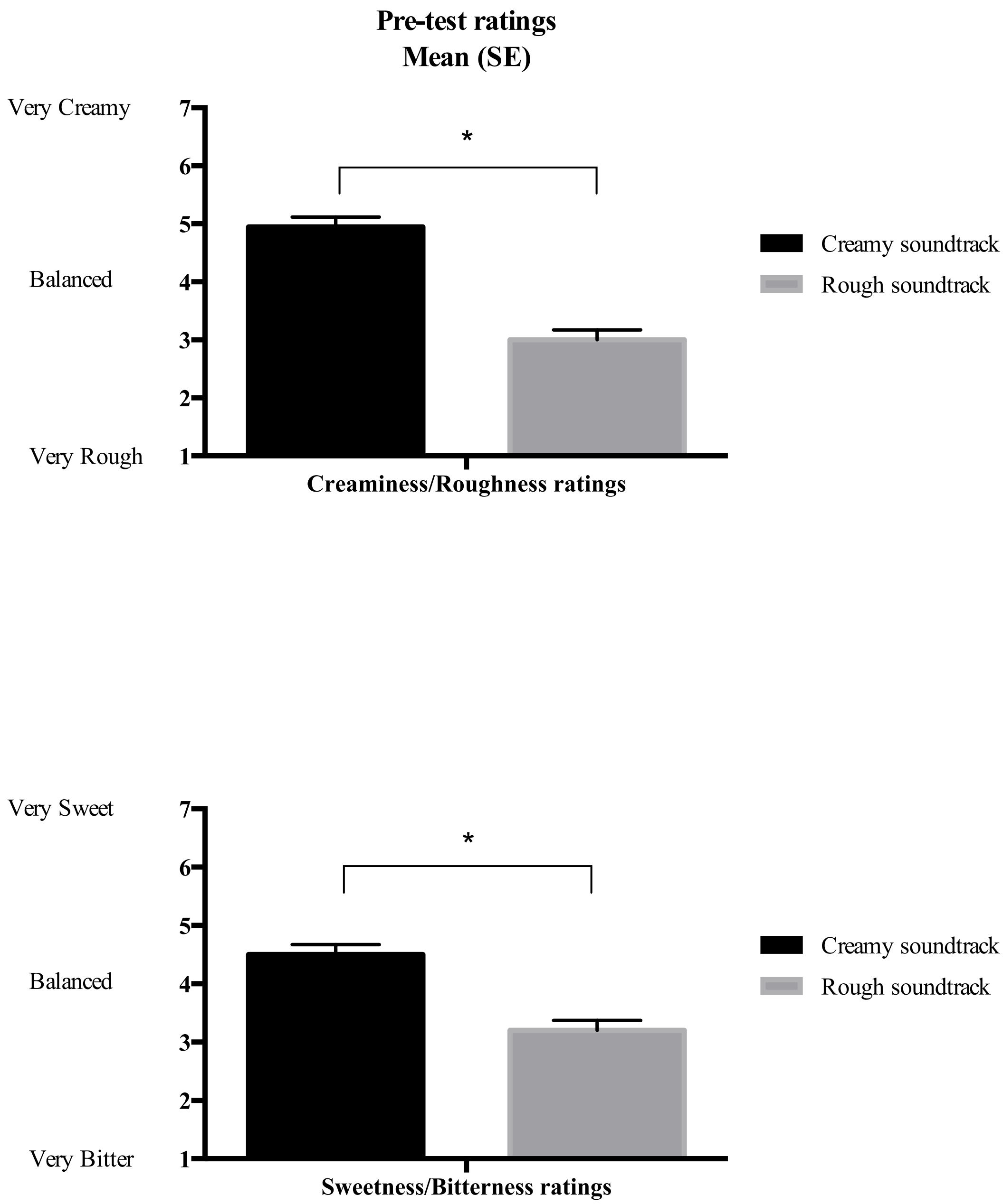

Figure 2. Mean values of the pre-test ratings (based on 7-point scale). Error bars indicate standard error (SE). Asterisk (‘*’) indicate a significant difference at p < .005.

2.3 Design and Procedure

Design: The study was approved by the Social Ethics Committee at KU Leuven – SMEC (Protocol G2016 03 519). Different participants tasted and rated two identical chocolates in two trials, each time listening to one of the two soundtracks (all ratings based on 7-point scales; see supplementary material for complete questionnaire). The independent variables for each experiment were sound condition (within-participants) and chocolate type (between-participants). The dependent variables were the ratings that the participants made for each trial. The soundtracks were presented in a counterbalanced order across participants. The order of presentation of the questions was fully randomized as well.

Procedure: The ninth floor of the Musical Instruments Museum Brussels (mim) was chosen as the site for the experiments. Due to its independent location inside of the museum, being located between the museum's restaurant on the top floor and the rest of the exhibitions below, it was possible to have a well-controlled experimental environment during experimental hours. Four rectangular tables were placed in the experimental area, one for each experiment, with two computers on each table. The natural light present in the experimental area was sufficient to provide a more 'intimate' ambience. Therefore, artificial light was kept to a minimum.

Each participant was seated in front of a computer screen. Each participant had three chocolates, a glass of tap water, a pair of headphones, a computer mouse, and a keyboard to interact with the survey. The calibration of the reproduction system was set to a comfortable – but at the same time immersive – listening level of Leq_{1min} = 70 +/- 3dB (corresponding to 50% of the volume of the existent sound system). The soundtracks were presented over SONY MDRZX310 headphones. Note that the participants were not able to hear the sounds from the other participants' headphones.

The survey consisted of an electronic form containing three main steps. In the first step of the survey, the participants were instructed to read and accept the conditions of the informed consent before entering their personal details. They were instructed to drink water before eating each one of the experimental chocolates. Prior to eating, the participants were also instructed not to chew the chocolates, but to let them melt inside the mouth. This instruction was included in order to help standardizing the way that all the participants experienced the texture of the experimental chocolates (see supplementary material for complete instructions).

In a second step, the participants had to taste a small drop of bitter chocolate, as a covariant (such chocolate drop was part of an industrial batch of 'Callebaut Dark Callets', recipe 70-30-38, with 70.5% cocoa). Here, they rated how much they liked it, and how sweet, bitter, and creamy they thought that it was. In this part of the experiment, the participants tasted and rated the chocolate without any sound.

In the third and final step, the participants were randomly assigned to one of four groups. This assignment defined which of the four available chocolate types (71% angular, 71% round, 80% angular, or 80% round) they would taste (see Figure 1). Here, they had to taste and rate the same chocolate twice, each time listening to one of the two soundtracks. Both chocolates were numbered. Hence, the participants were instructed to eat chocolate Number 1 first, while listening to the first soundtrack, and then chocolate Number 2, while listening to the second soundtrack. After tasting each chocolate, they rated how much they liked it, how sweet, bitter, and creamy they thought it was. They also rated how much they liked each soundtrack, and how much they thought it matched the taste of the chocolate (all ratings based on individual 7-point scales, with '1' being 'Not at all', '4' 'Neutral' and '7' 'Very much'; see supplementary material for complete questionnaire).

Together with the written guidelines concerning the experiment, at least one supervisor was present during the experiment in order to provide guidance and support. Upon finishing the experiment, the participants were instructed to leave the room without discussing any details with the next group of participants. The experiment lasted for around 10 minutes.

Data analysis: A repeated-measures multivariate analysis of variance (RM-MANOVA) test was performed, with soundtrack condition as the within-participant factor, and chocolate type (shape/cocoa content) as the between-participants factor. Furthermore, we calculated Pearson's correlation coefficients for participant ratings in order to understand any relationships behind the participants' evaluations. All of the post-hoc pairwise comparisons were Bonferroni corrected.

3. Results

Multivariate tests: Chocolate type did not have a significant effect on the participants' ratings ($F(18,327) = .1.46$, $p = .103$, partial $\eta^2 = .074$), but soundtrack condition did ($F(6,107) = 6.26$, $p<.005$, partial $\eta^2 = .260$). More specifically, participants reported that the chocolates tasted creamier while listening to the creamy soundtrack, as compared to the rough soundtrack (p = .002; Mean creamy soundtrack = 4.07, SE = .14; Mean rough soundtrack = 3.67, SE = .14). The participants also reported that the chocolates tasted sweeter while listening to the creamy soundtrack (p = .004; Mean creamy soundtrack = 3.77, SE = .13; Mean rough soundtrack = 3.39, SE = .12), and that the chocolates tasted more bitter while listening to the rough soundtrack (p = .010; Mean creamy soundtrack = 3.92, SE = .12; Mean rough soundtrack = 4.23, SE = .12).

Moreover, the participants reported having liked the creamy soundtrack significantly more than the rough soundtrack (p < .005; Mean creamy soundtrack = 3.64, SE = .16; Mean rough soundtrack = 2.53, SE = .13). When comparing how well they thought the soundtracks matched the taste of the chocolates, a trend suggested that the creamy soundtrack might have been a better match than the rough soundtrack (p = .077; Mean creamy soundtrack = 3.74, SE = .15; Mean rough soundtrack = 3.36, SE = .15). Finally, no significant differences were found in terms of participants' enjoyment of the chocolates when comparing the two soundtrack ratings (p = .161; Mean creamy soundtrack = 4.49, SE = .12; Mean rough soundtrack = 4.32, SE = .13; see Figure 3).

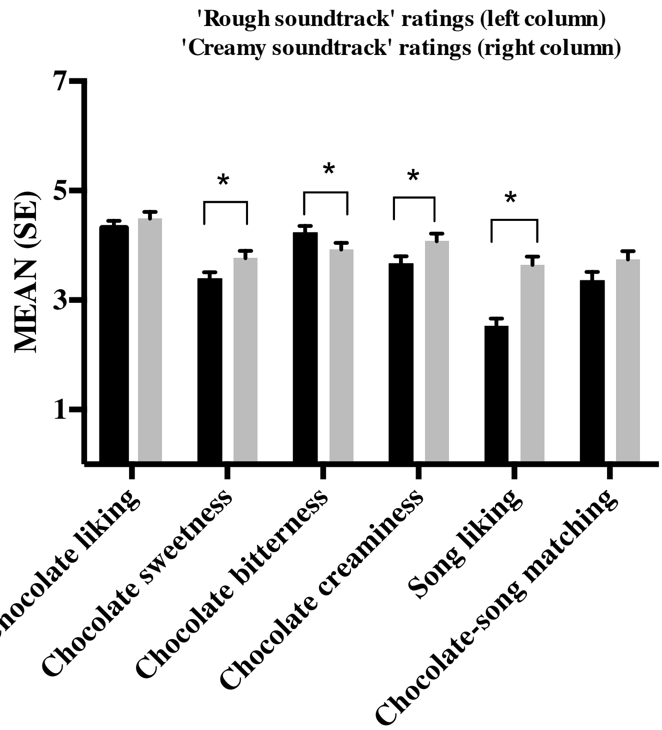

Figure 3. Participants' mean ratings (based on 7-point scale). For each attribute, the left column (black) corresponds to rough soundtrack ratings, and the right column

(gray) to creamy soundtrack ratings. Error bars indicate standard error. Asterisks '*' indicate a significant difference at p = .010, between the rough and creamy soundtracks ratings.

The participants were further subdivided in two groups – those who liked the creamy soundtrack more than the rough soundtrack (N=71), and the rest (N=38). Such a grouping – namely 'soundtrack preference' – was included as an independent variable as part of the main analysis. Here, the results revealed a significant interaction between soundtrack condition and soundtrack preference ($F(6,109) = 47.89$, $p<.005$, Pillai's Trace=.98), in particular for chocolate liking ($F(1,114) = 12.51$, $p=.01$, partial $\eta^2= .10$), chocolate-soundtrack match ($F(1,114) = 32.44$, $p<.005$, partial $\eta^2= .22$), and creaminess ($F(1,114) = 5.02$, $p=.027$, partial $\eta^2= .04$). For chocolate liking and chocolate-soundtrack match, the participants tended to give a higher rating to whichever soundtrack they preferred. However, for creaminess ratings, Bonferroni-corrected post-hoc testing revealed that only the group that preferred the creamy soundtrack reported higher creaminess ratings while listening to the creamy soundtrack ($p<.005$). By contrast, there was no significant interaction effect of soundtrack condition and soundtrack preference on sweetness ($F(1,114) = 0.41$, $p=.52$) or bitterness ratings ($F(1,114) = 0.65$, $p=.42$).

Correlations: Table A shows the calculated correlations (See Appendix for Table A). Sweetness and creaminess ratings were positively correlated with chocolate liking, whereas bitterness ratings were negatively correlated with the three aforementioned attributes. Moreover, chocolate liking and creaminess were positively correlated with soundtrack liking and chocolate-soundtrack matching. Finally, soundtrack liking and chocolate-soundtrack matching were positively correlated. In summary, there was a positive relationship between soundtrack liking, chocolate liking, and chocolate sweetness/creaminess ratings.

4. Discussion

In the present study, two soundtracks were produced with the aim of modulating the perceived creaminess of chocolate. The first soundtrack was produced to be congruent with creaminess, and the second with roughness. Note that both soundtracks were compared and validated by means of a pre-test. In total, four chocolate samples were produced, with a combination of two shapes (round/angular) and two formulas (71% and 80% cocoa). The participants were subdivided into four groups, one corresponding to each of the available chocolate types. In each group, the participants tasted and rated the same chocolate twice, each time under the influence of one of the soundtracks.

The results revealed that the soundtracks had the predicted effect on the perceived creaminess of the chocolates (see Figure 3). In particular, the creamy soundtrack significantly elevated ratings on creaminess, when compared to the effects of the rough soundtrack (that potentially decreased the perceived creaminess). In addition, there was a direct relationship between ratings of sweetness and creaminess. Table A reveals that creaminess and sweetness ratings were positively correlated, whereas creaminess was negatively correlated with bitterness. These correlations also highlight the fact that creaminess and sweetness are positively correlated with chocolate liking (see Table A). One possible explanation for these correlations is that there may have been a general confound in the mind of the participants between creaminess and sweetness ratings. In particular, sweetness was perhaps used as a proxy for creaminess. Two analogous cases have been reported previously with alcoholic beverages, where those who are generally poor at estimating alcohol content, may use taste cues as a substitute. For instance, Stafford et al. (2012) reported that ratings of alcohol content was correlated with bitterness ratings in vodka when participants tasted a variety of vodka-juice mixtures at different alcohol levels. On top of that, it seems that high-impact flavor may be used as a proxy for alcohol content as well, such as hoppiness/bitterness in the case of beer (i.e., Reinoso Carvalho et al., 2016; see also Harrar et al., 2013).

It is also important to highlight the fact that, when producing the creamy soundtrack, some musical attributes that were here considered as congruent with creaminess, are also parameters that are usually correlated with sweetness. The same goes for the musical attributes that were here considered as congruent with roughness, which are also commonly correlated with bitterness. For example, consonance (melodic and/or harmonic), legato articulation, and low discontinuity are all musical parameters that were previously reported as being congruent with sweetness. Here the abovementioned parameters were used to be congruent with creaminess as well. On the other hand, higher discontinuity and dissonance (in this case harmonic) are parameters that were previously reported as congruent with bitterness, and were here used as incongruent with creaminess (see Knöferle & Spence, 2012; and Knoeferle et al., 2015, for a review on musical and psychoacoustic parameters and their correspondent congruency with basic taste attributes). That being said, it would be plausible that these soundtracks could also have had an enhancing effect on the perceived texture of the chocolates while, in parallel, potentially having a perceptual effect on the chocolate's sweetness and bitterness.

In general, the participants liked the creamy soundtrack significantly more than the rough soundtrack. On the basis of this result, it could be presumed that the greater enjoyment of the creamy soundtrack could have enhanced chocolate liking (Kantono et al., 2015; Kantono et al. 2016; see Cheskin, 1972, and Spence, 2016, on the notion of sensation transference), which then heightened the perceived creaminess of the chocolate (shown in the correlations present in Table A). A further subdivision of the data (splitting the participants by soundtrack preference) revealed that only those who preferred the creamy soundtrack rated the chocolate as creamier while listening to the creamy soundtrack, thus implying a role of sensation transference in modulating participants' responses. It is equally important to note that we did not observe a similar interaction effect for either sweetness or bitterness ratings.

Furthermore, such differences in people's liking for the soundtrack did not affect their overall enjoyment of the chocolates[1] (see Figure 3). Previous similar studies have reported that music tends to have an effect in the hedonic and perceptual ratings on food/beverages multisensory tasting experiences, with sound enhancing the enjoyment of food and drinks (cf. Kantono et al., 2016; Reinoso Carvalho et al., 2015b; Spence et al., 2013).

The results reported here may well prove useful for innovators in the food industry. They demonstrate that sounds can, in some cases at least, have a perceptual effect on food without altering its hedonic experience, regardless of the fact that people might prefer one sound stimulus over the other (cf. Wang & Spence, 2015b). The results of the present study reveal that the soundtracks that were produced specifically for this study could be considered as a reliable baseline for the production of other soundtracks, to be used in future similar assessments.

[1] Although we did observe individual correlations between soundtrack liking and chocolate liking, which is in line with results from Wang and Spence (2015b).

Nevertheless, there are a few limitations of the present study that are worth mentioning here and which deserve to be assessed in future work. Principally, with these results it is difficult to conclude whether there is only one, or perhaps several mechanisms underlying these sound-chocolate associations. It would appear that there are a number of explicit crossmodal sound-flavor correspondences, driven mainly by the salient musical attributes of each soundtrack. However, since there is a clear correlation between soundtrack and chocolate liking, it could be argued that the present results hinge on some form of sensation transference effect rather than reflecting a 'true' crossmodal correspondence, at least when it comes to the creaminess ratings. Still, most of the musical attributes used in these exercises were chosen on the basis of contrast (think of consonant versus dissonant harmonies, reverberant versus dry ambiances, and so on). That being said, a plausible assumption would be that assessments such as this one would most likely be under the constant subjective preference of each participant, especially when working with those individuals lacking of specific musical training. For instance, most people prefer listening to consonant harmonies over dissonant ones, and so on.

Moreover, it is also worth highlighting the fact that the soundtracks produced for this experiment are simple in terms of their musical composition (see Section 2.2). A similar exercise could use more complex sound stimuli (i.e., with more instrumental layers and/or more sound effects). This way it would be possible to assess the potential of, for example, using popular music formats in order to modulate the perceived creaminess of chocolate (just think of all the music, e.g., advertising jingles, that are not produced with any thought given to sound-taste correspondences, but which could nevertheless still have a perceptual effect on people's perception of food and beverages).

In this discussion, we argue that sweetness may have been used as a proxy for creaminess, and that this might be the product of confound. Such confound may be related to some kind of halo-dumping effect as well. Similar research has shown that flavor ratings may be affected by the usage of repeated category ratings. For instance, a decrease in sweet-intensity ratings was previously observed when participants were given flavor and sweetness response alternatives that when they were given only a single sweetness scale as option for rating (Clark & Lawless, 1994). Such observations in mind should be considered while designing future similar experiments.

Here, it is interesting to note that the different types of chocolate (shape and cacao content) did not have a significant impact on our results. Previously, by contrast, it has been reported that round shapes tend to be associated with creaminess (see Yorkston & Menon, 2004, for the association of round vowel sound with creaminess), and food with a rougher surface can be perceived as sourer, when compared with food samples having a smoother surfaces (Slocombe et al., 2016). Moreover, previous research has also revealed that people tend to match sweeter chocolates with rounder shapes, and chocolates that are more bitter with angular shapes (Ngo, Misra, & Spence, 2011; Gallace, Boschin, & Spence, 2011; see Spence & Deroy, 2012, for a more general approach on the relation of shapes and taste/flavors; though see also Bremner et al., 2013, for cross-cultural differences). Apparently such changes in shape can affect the experience of consumers. For example, recently, a number of customers reported having experienced a sweeter new version of a milk chocolate bar, whereas the company (Cadbury) stated that the only thing that had changed in the novel chocolate's design was its shape - from an old rectangular design into a new rounder one[2,3] (Spence, 2014). Of course, in our experimental design, the shape and cacao content of the chocolates were varied on a between-participants basis, and soundtrack condition was a within-participants variable. Using such a design, the soundtracks had a significant effect on the perceived taste and creaminess of the chocolates, whereas there was no apparent effect of the differences of the chocolates samples on ratings. Future complementary research could rehearse inverting the design/factors and implement, for example, different groups of soundtracks, where people listen to the same soundtrack twice, eating each time a chocolate with different shapes. Should a different pattern of results be obtained under such conditions, this might well add weight to the claim that crossmodal correspondences typically rely on explicit contrast for their effectiveness (Spence, 2011).

Finally, in future experiments it would perhaps also be interesting to assess the

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[2] See "Revolt over Cadbury's' rounder, sweeter' bars: Not only has the classic rectangle shape of a Dairy Milk changed, customers say they are more 'sugary' too". From *Daily Mail Online*, *16th September, 2013*. Downloaded from http://www.dailymail.co.uk/news/article-2421568/Revolt-Cadburys-rounder-sweeter-bars-Not-classic-rectangle-shape-Dairy-Milk-changed-customers-also-sugary.html

[3] The aforementioned complains didn't seem to have affected the decision of updating the shape of one of Cadbury's flagships, the 'Roses Chocolates'. They claim that such update will allow a maximum enjoyment of this chocolate's flavor. See "Cadbury changes roses chocolates for first time in almost 80 years". From *Europe Newsweek, April 21st, 2016*. Downloaded from http://europe.newsweek.com/cadbury-changes-roses-chocolates-after-almost-80-years-450633?rm=eu

potential perceptual effect that these sounds may have on other types of chocolate (such as milk-based ones). A comparison between, for example, a wider contrast between chocolate formulas (i.e. a milk-based versus a more bitter chocolate - such as the ones we are using here), may provide us with new insights. In such a case, it should also be considered that these chocolates would most likely have significantly different colors. Therefore, a solution in this case may be to artificially color all the chocolates within the same color range, although this might bring other visual factors into the experimental design that would be necessary to consider as well.

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6. References

Bremner, A., Caparos, S., Davidoff, J., de Fockert, J., Linnell, K., & Spence, C. (2013). Bouba and Kiki in Namibia? A remote culture make similar shape-sound matches, but different shape-taste matches to Westerners. *Cognition, 126*, 165-172.

Bronner, K., Bruhn, H., Hirt, R., & Piper, D. (2012). What is the sound of citrus? Research on the correspondences between the perception of sound and flavour. In *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.

Clark, C. C., & Lawless, H. T. (1994). Limiting response alternatives in time-intensity scaling: An examination of the halo dumping effect. *Chemical Senses*, *19*, 583-594.

Crisinel, A.-S., Cosser, S., King, S., Jones, R., Petrie, J., & 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 Quality and Preference, 24*(1)*,* 201-204.

Cheskin, L. (1972). *Marketing success: How to achieve it*. Boston, MA: Cahners Books.

Eitan, Z., & Rothschild, I. (2010). How music touches: Musical parameters and listeners' audiotactile metaphorical mappings. *Psychology of Music*, *39*(4), 449-467.

Gallace, A., Boschin, E., & Spence, C. (2011). On the taste of "Bouba" and "Kiki": An exploration of word-food associations in neurologically normal participants. *Cognitive Neuroscience*, *2*, 34-46

Harrar, V., Smith, B., Deroy, O., & Spence, C. (2013). Grape expectations: How the proportion of white grape in Champagne affects the ratings of experts and social drinkers in a blind tasting. *Flavour*, *2*:25.

Kantono, K., Hamid, N., Sheperd, D., Yoo, M. J. Y., Carr, B. T., & Grazioli, G. (2015). The effect of background music on food pleasantness ratings. *Psychology of Music, 44*(5), 1111-1125.

Kantono, K., Hamid, N., Shepherd, D., Yoo, M. J., Grazioli, G., & Carr, B. T. (2016). Listening to music can influence hedonic and sensory perceptions of gelati. *Appetite, 100*, 244-255.

Knight, T. (2012). Bacon: The slice of life. In *The kitchen as laboratory: Reflections on the science of food and cooking* (eds. C. Vega, J. Ubbink and E. van der Linden), pp. 73-82. New York, NY: Columbia University Press.

Knöferle, K., & Spence, C. (2012). Crossmodal correspondences between sounds and tastes. *Psychonomic Bulletin & Review*, *19*, 1-15.

Knoeferle, K. M., Woods, A., Käppler, F., & Spence, C. (2015). That sounds sweet: Using crossmodal correspondences to communicate gustatory attributes. *Psychology & Marketing*, *32*, 107-120.

Köhler, W (1929). *Gestalt psychology*. New York, NY: Liveright.

Köhler, W. (1947). *Gestalt psychology: An introduction to new concepts in modern psychology*. New York: Liveright.

Ngo, M., Misra, R., & Spence, C. (2011). Assessing the shapes and speech sounds that people associate with chocolate samples varying in cocoa content. *Food Quality & Preference*, *22*, 567-572.

Reinoso Carvalho, F., Van Ee, R., Rychtarikova, M., Touhafi A., Steenhaut, K., Persoone, D., Spence, C. & Leman, M. (2015a). Does music influence the multisensory tasting experience? *Journal of Sensory Studies, 30*(5), 404-412.

Reinoso Carvalho, F., Van Ee, R., Rychtarikova, M., Touhafi, A., Steenhaut, K., Persoone, D., & Spence, C. (2015b). Using sound-taste correspondences to enhance the subjective value of tasting experiences. *Frontiers in Psychology*, *6*:1309.

Reinoso Carvalho, F., Van Ee, R., & Touhafi, A. (2013). T.A.S.T.E. Testing Auditory Solutions Towards the improvement of the Tasting Experience. In *Proceedings of* 10^{th} *International Symposium on Computer Music Multidisciplinary Research* (pp. 795-805). Marseille: L.M.A. Publications.

Reinoso Carvalho, F., Van Ee, R., Touhafi, A., Steenhaut, K., Leman, M. & Rychtarikova, M., (2015c). Assessing multisensory tasting experiences by means of customized sonic cues. In *Proceedings of Euronoise 2015, 352* (pp. 1-6). Maastricht

Reinoso Carvalho, F., Wang, Q. J., Van Ee, R., & Spence, C. (2016). The influence of soundscapes on the perception and evaluation of beers. *Food Quality and Preference*, *52*, 32-41.

Salgado-Montejo, A., Alvarado, J. A., Velasco, C., Salgado, C. J., Hasse, K., & Spence, C. (2015). The sweetest thing: The influence of angularity, symmetry, and the number of elements on shape-valence and shape-taste matches. *Frontiers in Psychology*, *6,* 1382.

Seo, H.-S., & Hummel, T. (2011). Auditory–olfactory integration: Congruent or pleasant sounds amplify odor pleasantness. *Chemical Senses*, *36*(3), 301-309.

Seo, H.-S., Lohse, F., Luckett, C. R., & Hummel, T. (2014). Congruent sound can modulate odor pleasantness. *Chemical Senses*, *39*(3), 215-228.

Slocombe, B. G., Carmichael, D. A., & Simner, J. (2016). Cross-modal tactile-taste interactions in food evaluations. *Neuropsychologia, 88*, 58-64.

Spence, C. (2011). Crossmodal correspondences: A tutorial review. *Attention, Perception, & Psychophysics*, *73*(4), 971-995.

Spence, C. (2012). Auditory contributions to flavour perception and feeding behaviour. *Physiology & Behavior*, *107*(4), 505-15.

Spence, C. (2014) Assessing the influence of shape and sound symbolism on the consumer's response to chocolate. *New Food Magazine*, *8th December*. http://www.newfoodmagazine.com/advent-calendar/assessing-the-influence-of-shape-and-sound-symbolism-on-the-consumers-response-to-chocolate/.

Spence, C. (2015a). 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. (2015b). Multisensory flavor perception. *Cell*, *161*(1), 24-35.

Spence, C. (2016). Sound bites and digital seasoning. In Sorensen, V. (Ed.), *Sound,* *media art, and the metaverse*. [ICMA Array (Lindborg, P.-M., & Styles, S. eds.), vol 2016, Special Issue: Proceedings of Si15, Singapore, August 2015], pp. 9-15.

Spence, C., & Deroy, O. (2012). On the shapes of tastes and flavours. *Petits Propos Culinaires*, *97*, 75-108.

Spence, C., Michel, C., & Smith, B. (2014). Airplane noise and the taste of umami. *Flavour*, *3:*2.

Spence, C., & Piqueras-Fiszman, B. (2014). *The perfect meal: The multisensory science of food and dining*. Oxford, UK: John Wiley & Sons.

Spence, C., & Shankar, M. U. (2010). The influence of auditory cues on the perception of, and responses to, food and drink. *Journal of Sensory Studies*, *25*(3), 406-430.

Stafford, L. D., Fernandes, M., & Agobiani, E. (2012). Effects of noise and distraction on alcohol perception. *Food Quality & Preference*, *24*, 218-224.

Wang, Q. (J.), & Spence, C. (2015a). Assessing the influence of the multisensory atmosphere on the taste of vodka. *Beverages*, *1*, 204-217.

Wang, Q. (J.), & Spence, C. (2015b). Assessing the effect of musical congruency on wine tasting in a live performance setting. *i-Perception, 6*:3.

Wang, Q. (J.), & Spence, C. (2016). 'Striking a sour note': Assessing the influence of consonant and dissonant music on taste perception. *Multisensory Research*, *29*, 195-208.

Yarmolinsky, D. A., Zuker, C. S., & Ryba, N. J. (2009). Common sense about taste: from mammals to insects. *Cell*, *139*(2), 234-244.

Yorkston, E., & Menon, G. (2004). A sound idea: Phonetic effects of brand names on consumer judgments. *Journal of Consumer Research*, *31*, 43-51.

Appendix

	Chocolate Liking	Chocolate sweetness	Chocolate bitterness	Chocolate creaminess	Soundtrack liking	Chocolate-soundtrack match
Chocolate liking	1	**.329**	**-.140**	**.360**	**.256**	**.251**
Chocolate sweetness	**.329**	1	**-.296**	**.424**	**.168**	.054
Chocolate bitterness	**-.140**	**-.296**	1	**-.252**	-.048	.076
Chocolate creaminess	**.360**	**.424**	**-.252**	1	.232	**.189**
Soundtrack liking	**.256**	**.168**	-.048	**.232**	1	**.525**
Chocolate-soundtrack match	**.251**	.054	.076	**.189**	**.525**	1

Table A. Pearson correlation coefficients between participants' ratings for each of three experiments. Bold indicates significant correlations at the .05 level.