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Sweet and sour: music and taste associations

Introduction

Our enjoyment of food is multisensory in nature. All five senses have their specific role: the visual appearance and the odor of the dish create expectations about its taste and, during eating, a combination of taste, smell, touch, and hearing stimuli integrate into an overall multisensory perception of food. Senses do not operate in isolation, but synergize with one another. Interaction between odor and taste (King *et al.*, 2006), sight and taste (Koch and Koch, 2003; Spence *et al.*, 2010) and many other interactions among different senses are thoroughly reviewed for example by Ernst and Bühlhoff (2004). Since the 1960s, the interaction between auditory and taste perception has attracted academic attention (Holt-Hansen, 1968). This has driven a diverse field of related research (e.g., Beeli *et al.*, 2005; Hänggi *et al.*, 2008; Crisinel and Spence, 2009; 2010a; 2010b; Simner *et al.*, 2010; Mesz *et al.*, 2011).

There is a relationship between auditory cues and the perception of taste and the flavor of foods (Knöferle and Spence 2012). When people discuss about food or music, they often have a tendency to use the same adjectives to describe them. Adjectives, such as sweet, dry, light, soft, crisp are used to describe the qualities of both food and music. People make cross-modal associations between the tastes and sounds (e.g., Crisinel and Spence, 2009; 2010a; 2010b; Simner *et al.*, 2010; Mesz *et al.*, 2011; Bronner, 2012). For example, in the study of Crisinel and Spence (2010a), participants associated sweet and sour taste solutions' tastes to high-pitched sounds, bitter taste to the low-pitched sounds, and salty tastes to medium-pitched sounds.

Taste words can elicit consistent musical patterns (Mesz *et al.* 2011). Musicians were asked to improvise about the theme of basic taste words (e.g., “sweet,” “salty,” “bitter,” and “sour”). The results showed that, for example, the taste word “sweet” elicited musical patterns that were consonant, slow and soft, while “sour” elicited musical patterns that were high-pitched and dissonant. “Bitter” improvisations were low-pitched and legato. However, as Knöferle and Spence (2012) point out, the informative value of the findings might be limited because of the use of taste words rather than actual taste solutions. In turn, Crisinel *et al.*, (2012) were first to demonstrate that

a “bitter” background soundtrack caused food samples (such as bittersweet toffee) to be rated as more bitter than during a “sweet” background soundtrack.

Here, we investigated whether the “sweet” and “sour” musical patterns of four different musical pieces have an effect on participants’ taste associations. This study builds on Mesz *et al*’s (2011) findings on *consistent taste–musical patterns*. In addition to verbal and descriptive associations, this experiment is extended to study how music, which contains sweet or sour musical patterns, may influence how we prepare and cook food. This was done by measuring, quantitatively, sugar and acid contents of drinks, which were prepared based on musical associations.

Methods and materials

Selection of tastes and food items: a pre-test

A pre-test was conducted to identify food items for the field study that represents primarily one of the taste dimensions (i.e., sweet, sour, bitter, or salty) for typical consumers in South Ostrobothnia, Finland. Eight participants, recruited from a local food club, were asked to taste and mark 28 foods into a map having four boxes each representing one of the four tastes: sweet, sour, bitter, and salty. The participants tended to mix, especially the tastes sour and bitter, in test foods. This confusion between bitter *versus* sour is rather common and exists in other studies, as well (e.g. Laaksonen *et al.*, 2013). For example, for the tastes of raspberry, bilberry, orange, grapefruit, red currant, and tomato, half of the participants mapped them primarily as sour and the other half as bitter. Thus sweet and sour tastes, being easy to identify and distinguish, were chosen for the actual experiment.

The pre-test results were used when selecting foods for the actual experiment. The aim was to select the same amount of sweet and sour ingredients with similar color (yellow) and structure (clear).

Selected ingredients for the experiment were: mango juice (100% of pre-test participants classified this juice as sweet), orange juice (50% of pre-test participants, sour; 38%, bitter; and 13%, sweet), grapefruit juice (50%, sour, 50% bitter), lemon juice (100%, sour), pineapple juice (100%, sweet) and liquid honey (100%, sweet).

Selection of “sweet” and “sour” musical pieces: a pre-test

A pre-test was conducted to identify the musical pieces that most strongly associated with sweet or sour. Eleven students, from Sibelius Academy’s Doctoral Programme for Music and Performance Arts, listened to 16 musical pieces (each lasting 30 seconds), which were selected based on Mesz *et*

al.'s (2011) research. These represented either “sweet” (musical elements of long duration, low dissonance, low articulation, and low loudness) or “sour” (musical elements of high pitch, long duration and high dissonance) music. After hearing each of the musical samples, the pre-testers were asked to make associations between music and taste. By using a 7-point Likert-scale, they mapped the sweetness, sourness, saltiness, and bitterness of the musical pieces. As a result, the following four musical pieces were chosen for the experiment:

- 1) *Trois Gymnopédies, No.2 Lent et triste* by Erik Satie, composed in 1888, piano music (http://www.youtube.com/watch?v=1loSL7CjE_w);
- 2) *Davidsbündlertänze, Op. 6 No. 18, Nicht schnell, C major, Eusebius* by Robert Schumann composed in 1837, piano music (<http://www.youtube.com/watch?v=jIHsNlwD6jQ>);
- 3) *Superscriptio* by Brian Ferneyhough, composed in 1981, flute music (<http://www.youtube.com/watch?v=dYnYimo8z2Q>);
- 4) Musical sample by Bruno Mesz, produced in 2012, fragments of transformed Argentinian tangos (<http://youtu.be/lfxdpNMYmlo>).

Satie's and Schumann's samples represented “sweet” and Ferneyhough's and Mesz's samples for “sour” music. The following musical parameters of these samples were analyzed: 1) Roughness, also called sensory dissonance, which quantified the beating frequencies; 2) Brightness was the proportion of high-frequency spectral energy of the sound; 3) Attack time was the time to reach maximum sound intensity of the note; and 4) Mean frequency in Hz. The results of this analysis can be seen in Table 1. The profiles of “sweet” and “sour” samples had distinctively different roughness and brightness, being higher in Ferneyhough's and Mesz's samples than in Schumann's and Satie's musical pieces.

Mesz *et al.* (2011) describe taste words “sweet” and “sour” with a list of qualitative values for musical parameters: “sweet” musical elements have long duration, low dissonance, low articulation, and loudness (soft), and “sour” musical elements have high pitch, long duration, and high dissonance. “Sweet” musical parameters are found from the Satie's and Schumann's samples. “Sour” musical parameters are found from Ferneyhough's and Mesz's samples.

Satie's and Schumann's pieces were performed by a pianist, but Ferneyhough's music was performed by a piccoloist. Mesz's piece was algorithmically generated using short fragments of tangos, which were transformed in pitch in order to be in the high piccolo and clarinet register,

speeded up in order to achieve a medium duration equal to that measured in the Mesz *et al.* (2012) experiments for the sour taste, and contrapuntally disposed in order to have high chordal dissonance.

TABLE 1.

Description of the field experiment: experimental design, data collection procedures, and preparing the drink sample

Science fair visitors, aged 16 or older, were recruited to participate in the field experiment. Four independent groups of consumers, without extensive musical or culinary training, were recruited for the experiment that took place in connection with a public science fair in Western Finland, September, 2012. The fair visitors were approached and asked whether they wanted to participate in a study involving music and food. Those consenting were led in small groups to a pre-arranged experimental room. The rooms contained a table with four to five seats that were secluded from each other by light obstructions. Study participants sat down at a table, which had a questionnaire (text-side down), a pencil, plastic mugs, spoons, wipers, and six, unlabeled containers containing the ingredients for mixing the drink. No rewards were given to the study participants.

The experiment started by playing the pre-tested music to the study participants. Each of the four groups listened to only one of the four, 30-second musical pieces: group A, listened to Satie; group B, Schumann; group C, Ferneyhough; and group D, Mesz. For every group, the musical piece was replayed throughout the total time (*circa* 20 minutes) of the experiment. The music loudness was not played too loud or quietly, but at an ambient level.

The questionnaire had four sections. First, the gender and age were queried. Second, the food-related associations triggered by the music was captured. Third, the study participants were asked to indicate their taste associations congruent with the music on a 7-point scale, which included six pre-selected food pairs in the following order: wheat-oat, chocolate-lingonberry, lemon-banana, chicken-beef, meringue-sourdough crisp rye-bread, and red currant-pineapple. Fourth, the study participants were requested to mix a drink congruent with the music by using ingredients available on the table. They were asked to write down the ingredients they used for it. The details of these measurements are disclosed below.

Sixty-six participants agreed to take part in the study. These participants were divided into four groups. Group A, Satie (n=18), consisted of nine female and nine male participants, and the mean age was 33 years. The demographics, in order, for group B; Schumann (n=12); C, Ferneyhough (n=20); and D, Mesz (n=15) were the following: five females and seven males with a mean age of 49; 14 females and five males, mean age 23; 11 females and four males, mean age 42, respectively. There was no difference in gender distribution among the groups, however age was unevenly distributed and there was a significant difference between the groups: Satie and Schumann ($p=0.008$), Schumann and Ferneyhough ($p<0.001$), and Ferneyhough and Mesz ($p<0.001$).

Measurement and analysis of dependent variables

Food-related associations. Study respondents were asked to listen to music and think about what kind of food-related ideas and associations it brings to their minds. An empty box was provided for submitting their answers, anonymously. The Latent Semantic Analysis, with word groups referring to either food names or to the composition, texture, temperature, and quality of food (Deerwester *et al.*, 1990; Diuk *et al.*, 2012) was conducted. The reference document corpus was the TASA corpus, with 300 dimensions. The word-by-word semantic similarity of each of the word group with “sweet” and “sour” was computed. This gave two series of similarity values (one series for “sweet” and another for “sour”). Values vary between -1 (semantically dissimilar to “sweet” or “sour”) and 1 (semantically similar to “sweet” or “sour”). The customary one-way ANOVA and *post hoc* Tukey’s t-tests were conducted to detect differences between the two similarity values in different groups.

Taste associations. Associations were determined by four, food word-pairs: 1) Banana–lemon, 2) Chocolate–lingonberry, 3) Meringue–crisp rye-bread, and 4) Pineapple–redcurrant. On the basis of the pre-test for tasting, banana, chocolate, meringue, and pineapple represented sweetness, and lemon, lingonberry, crisp rye-bread, and redcurrant represented sourness. Two filler/control food word pairs were also included: 1) wheat–oats and 2) chicken meat–beef meat. These items are generally considered to neutral. The food word pairs were shown to the study respondents and they were asked to indicate, on a 7-point scale, which one of the food-word-pairs describes precisely the taste of the music they were hearing. For example, in the food-word-pair, banana–lemon, extreme lemon had value one and extreme banana had value seven. From the given values a one-way ANOVA and *post hoc* Tukey HSD-tests were conducted to detect the effects of “sweet” and “sour” music on consumers’ taste associations.

Preparing the drink congruent with the music. The study participants were asked to listen to the music and prepare a drink congruent with it. Each participant listened to only one musical piece. First, they were asked to list the ingredients (selecting from mango juice, orange juice, grapefruit juice, lemon juice, pineapple juice, and liquid honey) they used for mixing their drink, and then they were asked to prepare a sample drink. Samples of 20 milliliters were collected for chemical analysis.

Chemical analysis. The sugar and acid concentrations were chemically analyzed from the drink samples. A sample of 50 ml was collected from each participant and samples were stored at -20°C until analyzed for their sugar and organic acid contents. Sugar and acid contents of the juices were analyzed by a high performance liquid chromatographic (HPLC) method based on Phenomenex applications ID 5504 and 5505 and the analysis method for acids was based on Phenomenex application ID 14270. The HPLC system, Waters, consisted of a Waters in-line degasser AF, 515 HPLC pump, 717plus autosampler, column oven, 2410 refractive index detector (for sugars) and 2487 dual λ absorbance detector (for organic acids). The Empower 3 software was used for data acquisition and analysis.

The eluent used for organic acid analyses was 20 mM phosphate buffer, pH 2.9. Potassium phosphate (monobasic $\geq 99\%$) was purchased from Sigma-Aldrich (Chemie GmbH, Steinheim) and ortho-phosphoric acid (85%) used for adjustment of pH from Merck (Darmstadt, Germany). The eluent used for sugar analysis was deionized water, filtered through Phenex Nylon 0.45 μm filter membrane (Phenomenex). Sucrose was purchased from Merck (Darmstadt, Germany), D(-)-fructose and citric acid were obtained from Sigma-Aldrich (Steinheim, Germany), D(+)-glucose was purchased from J.T.Baker (Denventer, Holland) and L(-)-malic acid from Acros Organics (Geel, Belgium). Each juice sample was analyzed in triplicate. Quantification was carried out with an external standard method. The concentrations of sugars and acids were expressed as g/l.

A one-way ANOVA and *post hoc* Tukey HSD-tests were conducted to detect the effects of “sweet” and “sour” music’s impact on sugar and acid contents of the drinks.

Results

Food-related associations

Food-related word associations, generated in the four experimental groups, revealed a consistent trend (Figure 1). The higher ranked words, in response to the sweet melodies, were chocolate, tasty and for the sour melodies fruits, sour. To quantify this observation, we measured the projection of this distribution of words to the sweet and the sour dimensions of semantic space using Latent Semantic Analysis (Table 2). In the groups, which had the “sweet” music (Satie and Schumann) was played, the connotations of food-related associations were significantly closer to the taste word “sweet” than to the taste word “sour.” In contrast, in the groups that had “sour” music (Ferneyhough and Mesz) played, such significant differences were not detected. Secondly, the key connotations of food-related associations produced in the “sour” music groups were significantly closer to the taste word “sour” than those produced in the “sweet” music groups, except in the case of the Schumann *versus* Ferneyhough groups. However, the key connotations of food-related associations produced in the “sweet” music groups were not significantly closer to the taste word “sweet” than those produced in the “sour” music groups. This experiment can be viewed as a mirror reflection of Mesz *et al* (2011). In their original work, Mesz *et al* showed that taste words elicit consistent musical formations. Our analysis demonstrated that specific musical formations formed by the musical dimensions of different tastes evoked a broad set of words, which consistently projected to semantic taste dimensions.

FIGURE 1A-D.

TABLE 2.

Taste associations

The results shown above indicate that "sweet and sour melodies" produce structured projections of free word associations. In the next experiment, we investigated whether they produce a consistent set of associations within a controlled and limited set of words, which correspond to sweet, sour, or neutral associations.

As described earlier, six food-word-pairs (of which, two were filler/control items) were chosen to measure the taste associations triggered by the music. The sweet food words included chocolate, banana, meringue, and pineapple, and the sour food words were lingonberry, lemon, crisp rye-bread (the literal translation from Finnish is *sour rusk*), and red currant. The filler/control food word pairs encompassed wheat *versus* oats and chicken *versus* beef. The presumption was that the “sweet” and

“sour” music would have an effect on study participants’ taste associations, as reflected by the variation in the food word selections.

In the cases of food word pairs, chocolate–lingonberry and lemon–banana, the results (Table 3) suggest that the “sweet” music (Satie and Schumann) elicited sweeter taste associations (stronger choice preference for chocolate and banana), while the “sour” music (Ferneyhough and Mesz) yielded greater sour taste associations (stronger choice preferences for lingonberry and lemon). In effect, the same pattern of results was obtained for the food word pair meringue–crisp rye bread (with the exception that Schumann’s sweet music did not produce different results as Ferneyhough’s and Mesz’s sour music).

Only in the case of the red currant–pineapple food-word-pair, the results were not in accordance with our expectations – no significant differences in the taste associations between the “sweet” and “sour” music groups emerged. The null results were also received in the analysis of the filler/control food word pair, wheat–oats. A surprising difference surfaced when the responses to the second filler/control food word pair-items (chicken–beef) were compared between the groups when listening to Schumann’s “sweet” and Ferneyhough’s “sour” music. The former seemed to have taste associations related to beef whereas the latter did the same in relation to chicken. This finding is discussed later in the concluding section of the article. Overall, the findings concerning the taste associations convey additional evidence for this study’s key hypothesis.

TABLE 3.

Ingredients chosen for a drink

Participants were asked to prepare a drink congruent with the music they heard and write down what ingredients they used for it. They could freely select the ingredients from the choice set of five juices and liquid honey (refer to the description of the pre-test in the Methods and Materials-section). This procedure had a resemblance to the color-matching experiments by Helmholtz, where participants had to adjust the mix of three different wavelengths of light to match a given color (see Trichromatic Theory of Color Vision, 2013).

As summarized in Table 4, the total use of ingredients with the higher sugar content (honey, mango juice, and pineapple juice) dominated when listening to “sweet” music but more sour ingredients (lemon and grapefruit juice) were used when listening to “sour” music. For example the total use of

liquid honey in the “sweet” and “sour” music experiment was 109 and 44 ml while the use of lemon juice was 34 and 160 ml, respectively.

TABLE 4.

Samples were taken from each of the drink for the chemical analysis. Based on total consumption and reported sugar and acid concentrations of the ingredients (Table 4) the sugar and acid concentrations were predicted to differ between the drinks mixed when study participants were exposed to “sweet” (Satie and Schumann) *versus* “sour” (Ferneyhough and Mesz) music. The results are shown in Table 5.

TABLE 5.

The average total sugar content of the drinks prepared in the room with the “sweet” music (Satie and Schumann) were higher (125.2 g/l and 121.2 g/l, respectively) than in the drinks mixed while hearing the “sour” music of Ferneyhough and Mesz (101.2 g/l and 93.6 g/l, respectively). There was a significant difference between the total sugar contents of the drinks mixed while listening to the music of Satie *versus* Mesz ($p=0.011$), but the difference between the total sugar contents of the drinks prepared while listening to the music of Satie *versus* Ferneyhough ($p=0.051$) was not significant.

The total acid contents were higher in the drinks prepared in the rooms with Ferneyhough’s and Mesz’s “sour” music being played (11.8 and 11.9 g/l, respectively) than in the drinks mixed in the rooms filled with Satie’s and Schumann’s “sweet” music (8.8 and 8.4 g/l, respectively). A significant difference in the total acid contents of the drinks prepared in the rooms with the music of Satie *versus* Ferneyhough ($p=0.002$) was found. A similar significant difference was observed between the “sweet” music of Satie and the “sour” music of Mesz ($p=0.003$), between the “sweet” music of Schumann and the “sour” music of Ferneyhough ($p=0.004$) and between the “sweet” music of Schumann and the “sour” music of Mesz ($p=0.005$). In turn, the differences between the “sweet” musical pieces of Satie and Schumann and between the “sour” musical pieces of Ferneyhough and Mesz were non-significant.

The results concerning the sugar:acid ratios mirrored those of total acid contents (see above). To conclude, the results from the chemical analysis are supportive of the notion that the exposure to the

“sweet” and “sour” music indeed affected study participants’ choices of ingredients for a drink they were requested to mix. “Sweet” music led to more sugary drinks and “sour” music to drinks with higher acidity.

Discussion and conclusions

The results indicate that exposure to the “sweet” musical piece and to the “sour” musical piece influences food-related thinking processes and even choice behaviors. This study provides further evidence concerning the quality of associations made between music and food of similar taste parameters. We found that the participants, when listening to music, which contained “sweet” and “sour” taste elements, made word associations connected to these elements. These associations influenced their selection of ingredients for a drink preparation. It also impacted the sweetness and sourness of the drink that they prepared.

The food-related word association analysis clearly indicated that individuals make consistent associations between the music and food that can be characterized as possessing either sweet or sour taste parameters. The same, freely associated words were chosen repeatedly by different people for a given music (Figure 1). The most often repeated words were chocolate (for Satie) and tasty (for Schumann), and other highly repeated words for the “sweet” music files revealed connections with pleasant tastes, softness, and warm temperatures. These words were: dessert, soft, velvety, creamy, enjoyable, wine, fine, warm, and sweet. In contrast, the most often repeated words associated to “sour” music files were fruits (for Ferneyhough) and sour (for Mesz), and other frequent words related to relatively more unpleasant taste sensations: hardness and coldness, pungent, hard, icy, cold, strong, sharp, spicy, burning, spicy, and bitter. The terms, berries and lemon appear often both for sweet and sour music selections.

The qualitative analysis of the word pairs showed that, when listening to Satie’s piece, rich in “sweet” musical elements, the participants preferred sweet food terms such as chocolate, banana and meringue over the less sweet options. However, this effect was not as pronounced in the case of Schumann’s music, which is similarly rich in “sweet” elements. Ferneyhough’s piece, carrying several “sour” musical elements, encouraged the participants to gravitate towards sour food terms, such as lingonberry and lemon. In the case of Mesz’s “sour” music, this effect was even stronger.

We showed that sweet or sour elements in the music may even contribute to the actual degree of sweetness (as measured by the sugar content) and sourness (as measured by the organic acid content) of drinks. The participants created and prepared drinks with similar characteristics while being exposed to this kind of music. Drinks prepared, while listening to “sweet” music, had higher sugar content as compared to when prepared under the influence of “sour” music. The drinks prepared under the influence of “sour” music resulted in their higher organic acid content. The effect of specific musical patterns on consumers’ food-related associations and behavioral choices are not documented. Consequently, presenting the first empirical evidence for it contributes to an emerging research that addresses cross-modal interactions, in the realm of consumption and cooking of food. Moreover, the incorporation of them as dependent variables instead of taste perception extends the current academic knowledge.

These novel findings, produced by qualitative and quantitative methods, are consistent with three recent discoveries. First, certain phonetic features (e.g., brand names) map to specific tastes (Spence, 2012). Second, changing the sonic properties of a non-musical background soundtrack can modulate consumers taste perceptions of food products (Crisinel *et al.*, 2012). Third, musical pieces such as Carl Orff’s *Carmina Burana* and Michael Brook’s *Slow Breakdown* can lead consumers to rate the taste of the same wine in the former case, as more “powerful and heavy” whereas in the latter case, as more “mellow and soft” (North, 2012).

In the search of the conceptual explanation for the effects observed in this study, North’s (2012) elaboration on the cognitive priming theory and symbolic meanings of music is a viable candidate. These attributes make the basic assumption that the same terms or concepts are used to characterize both musical and taste sensations (Knöferle and Spence, 2012). In effect, symbolic priming occurs when the presentation of musical stimulus triggers interpretation or symbolic associations, which, in turn, primes a characteristic that happens to be perceived at the same time (Spence and Deroy, 2013, p. 138). Applying these ideas here suggests that the “sweet” symbolic connotations of Satie’s and Schumann’s music and the “sour” symbolic connotations of Ferneyhough’s and Mesz’s music prime mental content that is connected with the concepts of “sweetness” and “sourness.” This activation results in the increased likelihood of corresponding food-related thoughts and behaviors due to unconscious expectations (Spence, 2012). Thus, after being asked to produce food-related associations while hearing “sweet/sour” music, predominantly sweet/sour ones will come to people’s minds. This favored sweet/sour ingredient addition when asked to mix a drink.

The research conducted concerning the priming effects of brands, in the field of consumer behavior, offers direct evidence for this account. The symbolic meaning of creativity is associated with companies such as the Apple[®] brand, while the symbolic meaning of smartness is associated with the IBM[®] brand, among American consumers (Fitzsimons *et al.*, 2008). This study reveals that the Apple[®]-primed consumers behave more creatively than the IBM[®]-primed consumers or controls. Thus, this theoretical rationale should be tested in the future in the research context that combines various “taste music” and food-related dependent variables (e.g., associations, expectations, sensory perception, emotion, food choices, and even cooking). For example, the food-related expectations and emotions generated after hearing “sweet,” “sour,” “bitter,” and “salty” music could be compared (cf. Sester *et al.*, 2013) and their role in modifying taste perceptions and other food-related processes should be analyzed.

It must be acknowledged, though, that in addition to symbolic priming, there are other alternative accounts for understanding cross-modal associations between music and taste: the amodality, mediation, and transitivity hypotheses. According to the amodality hypothesis, the coding of certain dimensions of sensory experiences (e.g., magnitude or space) is common across modalities. The mediation hypothesis asserts that some other indirect commonality (e.g., pleasantness or fastness) explains why all sensory experiences that share this dimension correspond. Finally, the transitivity hypothesis can be illustrated as follows. If a sensory feature A corresponds to a feature B in another modality, and B, in turn, corresponds to a feature C in a third modality, our brains will generate a cross-modal correspondence between A and C. (Deroy *et al.*, 2013). The validity of these explanatory formulations should be rigorously tested in future studies.

The study also demonstrates the complexity of experiments where the connection between music and taste is under examination. For example, the results concerning the food-word-pair red currant – pineapple were inconsistent with the expectations. Although pineapple has high sugar content (30%) and is often considered as sweet, its relatively high organic acid content (0.6%) may make tasters judge it as a sour rather than as a sweet food. Second, an interesting theoretical implication springs from the unexpected finding that Satie’s and Schumann’s “sweet” music evoked stronger beef-related taste associations, while Ferneyhough’s and Mesz’s “sour” music did the same with regard to chicken-related taste associations. Five participants of twelve associated Schumann’s piano music with “fine dining” and a restaurant milieu. Here, the question is not necessarily about the cross-modal associations between the auditory and gustatory stimuli, but about the activation (by the music) of inter-connected mental constructs (the linkage between fine dining and beef-

eating is postulated to be stronger than that of between fine dining and chicken-meat eating) (see also Areni and Kim, 1993). Still, this interpretation is speculative and needs to be verified by further studies.

This points to the importance of understanding the symbolic meanings of cultural objects, practices, and places (Allen *et al.*, 2008), especially when they are used as experimental stimuli (this was controlled in the present study *via* a pre-test). The fact that piano music is often played in fine restaurants is a plausible explanation for the surprising effect referred to above. More generally, this implies that the symbolic meanings of certain musical pieces (e.g., Beethoven's fifth symphony) are likely to be differently understood in different socio-cultural contexts (e.g., in a German city *vs.* in a Tanzanian rural village) (cf. Reyes, 2009). Thus, the cross-cultural perspective on the cross-modal effects between music and taste perception provides another avenue for future research.

Limitations of the study

The “sweet” and “sour” music were produced using different instruments. Since different instruments may exert distinct timbre effects on how consumers map sounds onto tastes (Crisinel and Spence, 2010a), using piano *versus* flute music is a potential confounder. Piano music is consistently associated with “sweetness” (Spence, 2012), and flute music is associated with acidity (Spence *et al.*, 2013). “Sweet” and “sour” music were selected for the experiment, because sweet and sour dimensions are easy to distinguish (see e.g. Mesz *et al.*, 2011). Individual factors, such as the pre-existing musical and the culinary expertise, coupled with the usage of and attitude towards the juices and honey (the ingredients that were available for mixing the drink), were not explicitly measured. These factors could have moderated the effects detected, although the random assignment of participants to the experimental groups should decrease the risk of such a bias, here.

Due to a lengthy experimental session (*ca.* 20 min), commencing in a real life setting, a between-subjects study design was, in practice, the only alternative. This design, however, is suboptimal because it cannot produce conclusive evidence that it was the musical elements (sweet *vs.* sour) that affected the ingredients chosen for the drink and not some other factors (e.g., certain idiosyncrasies in the sweet *vs.* sour experimental conditions). Thus, replication attempts employing within-subjects designs are more apt. Finally, there were no filler tasks in which the participants were asked to engage in before they started to prepare the drinks. Moreover, no control questions hinting at the presumed purpose of the study were posed to them. The questionnaire did not contain any terms or words that were directly related to sweetness or sourness and while the participants were being

recruited, they were given only a general idea of the study (e.g., that is dealt with musical associations). Various sources of potential confounds must be systematically controlled in future studies.

Practical implications

The key finding of this study also propels a few managerial implications. First, by carefully considering the symbolic meanings of the music used in different social situations, creating multimodal experiences and even subconscious expectations in people's minds is possible (Krishna, 2012). These subconscious expectations can, through the assimilation processes (Sester *et al.*, 2013), come to augment consumers' actual taste experience, which occur later. Second, ambient "taste music" that is congruent with the basic flavors of the dishes can be played in restaurants to highlight guests' sensory experiences. For instance, sweet desserts may be appreciated more when "sweet taste music" is aired (cf. Crisinel *et al.*, 2012). Third, food marketers can combine music or sounds with visual, haptic, and olfactory stimuli to produce an optimal mixture of taste emotions that increasingly fascinates sensory researchers at the moment (e.g., Ng *et al.*, 2013).

These findings suggesting that specific musical elements have an influence on how a dish is prepared may have compelling practical implications. Indeed, they encourage chefs and restaurant-keepers to develop new multimodal culinary experiences. As a matter of fact, such culinary innovations already exist. One of the landmark example of these are the "Sounds of the sea" dish served by Heston Blumenthal in the Fat Duck restaurant in Bray, UK. There, this dish is served while playing a soundtrack specifically designed for it to highlight the multimodal eating experience. Multimodal cookbooks, such as those including music recommendations for each dish, are a novel type of food literacy (e.g., Pelaccio, 2012). The significance of this study lies in the notion that a soundscape may influence the design and creation of culinary dishes. This represents a possibility to raise the culinary art to a new level.

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Music samples:

- Schumann: <http://www.youtube.com/watch?v=jIHsNlwD6jQ>
- Ferneyhough: <http://www.youtube.com/watch?v=dYnYimo8z2Q>
- Satie: http://www.youtube.com/watch?v=1loSL7CjE_w
- Mesz: <http://youtu.be/lfxdpNMYmlo>

Music	Roughness	Brightness	Attacktime	Mean frequency
Satie n=18	6.1	0.2	0.1	842.8
Schumann n=12	13.4	0.1	0.1	293.8
Ferneyhough n=20	29.2	0.9	0.1	1252.6
Mesz n=15	814.8	0.6	0.1	1085.7

TABLE 1. The musical parameters of selected “sweet” and “sour” musical samples.

Music/Word similarities	"sweet" (mean)	"sweet" (std)	"sour" (mean)	"sour" (std)	t-test "sweet" vs. "sour"
Satie n=18	0.3	0.15	0.21	0.13	p=0.00001
Schumann n=12	0.32	0.16	0.23	0.15	p=0.01
Ferneyhough n=20	0.34	0.13	0.30	0.20	p=0.2
Mesz n=15	0.35	0.19	0.33	0.27	p=0.6
Comparative similarity to "sweet" (t-test)					
Satie n=18	Satie n=18	Schumann n=12	Ferneyhough n=20	Mesz n=15	
Schumann n=12		p= 0.5397	p= 0.1424	p= 0.0990	
Ferneyhough n=20			p= 0.5352	p= 0.4324	
Mesz n=15				p= 0.7569	
Comparative similarity to "sour" (t-test)					
Satie n=18	Satie n=18	Schumann n=12	Ferneyhough n=20	Mesz n=15	
Schumann n=12		p= 0.3025	p= 0.0007	p= 0.0002	
Ferneyhough n=20			p= 0.06	p= 0.03	
Mesz n=15				p= 0.49	

TABLE 2. The semantic similarity values (mean and standard deviation std) of food-related word associations with the taste names "sweet" and "sour". Values of Latent Semantic Analysis vary between -1 (semantically dissimilar to "sweet" or "sour") and 1 (semantically similar to "sweet" or "sour"). The significance (p-value) of the differences between the groups (statistically significant differences marked bolded) was determined by ANOVA and the Tukey's t post hoc tests.

	Chocolate 1		Lemon 1		Chicken 1		Meringue 1		Redcurrant 1	
	Lingonberry 7	Banana 7	Banana 7	Beef 7	Crisp rye bread 7	Pineapple 7	Wheat 1	Oats 7		
p-value	p = 0.000	p = 0.000 ¹	p = 0.009 ¹	p = 0.003	p = 0.159	p = 0.732				
Satie n = 18	2.22 ± 1.48 ^A	4.72 ± 1.56 ^A	4.06 ± 2.04 ^{AB}	2.61 ± 1.42 ^A	3.56 ± 1.34	4.22 ± 1.48				
Schumann n = 12	3.00 ± 1.71 ^A	3.75 ± 1.96 ^A	5.33 ± 1.23 ^A	3.25 ± 1.82 ^{AB}	3.75 ± 1.66	3.83 ± 1.53				
Ferneyhough n = 20	5.55 ± 1.43 ^B	2.00 ± 1.45 ^B	2.95 ± 1.23 ^B	4.45 ± 1.61 ^B	3.80 ± 1.91	3.90 ± 1.21				
Mesz n = 15	6.29 ± 0.73 ^B	1.67 ± 0.82 ^B	3.53 ± 1.51 ^{AB}	4.47 ± 2.00 ^B	2.60 ± 1.59	3.37 ± 1.63				

TABLE 3. Taste associations evoked by the “sweet” (Satie and Schumann) and “sour” (Ferneyhough and Mesz) music. The significance (p-value) of the differences between the music groups (marked with letters A and B) was determined by ANOVA and the Tukey HSD post hoc tests. The mean values and standard deviations are reported in rows (e.g., 2.22 ± 1.48).

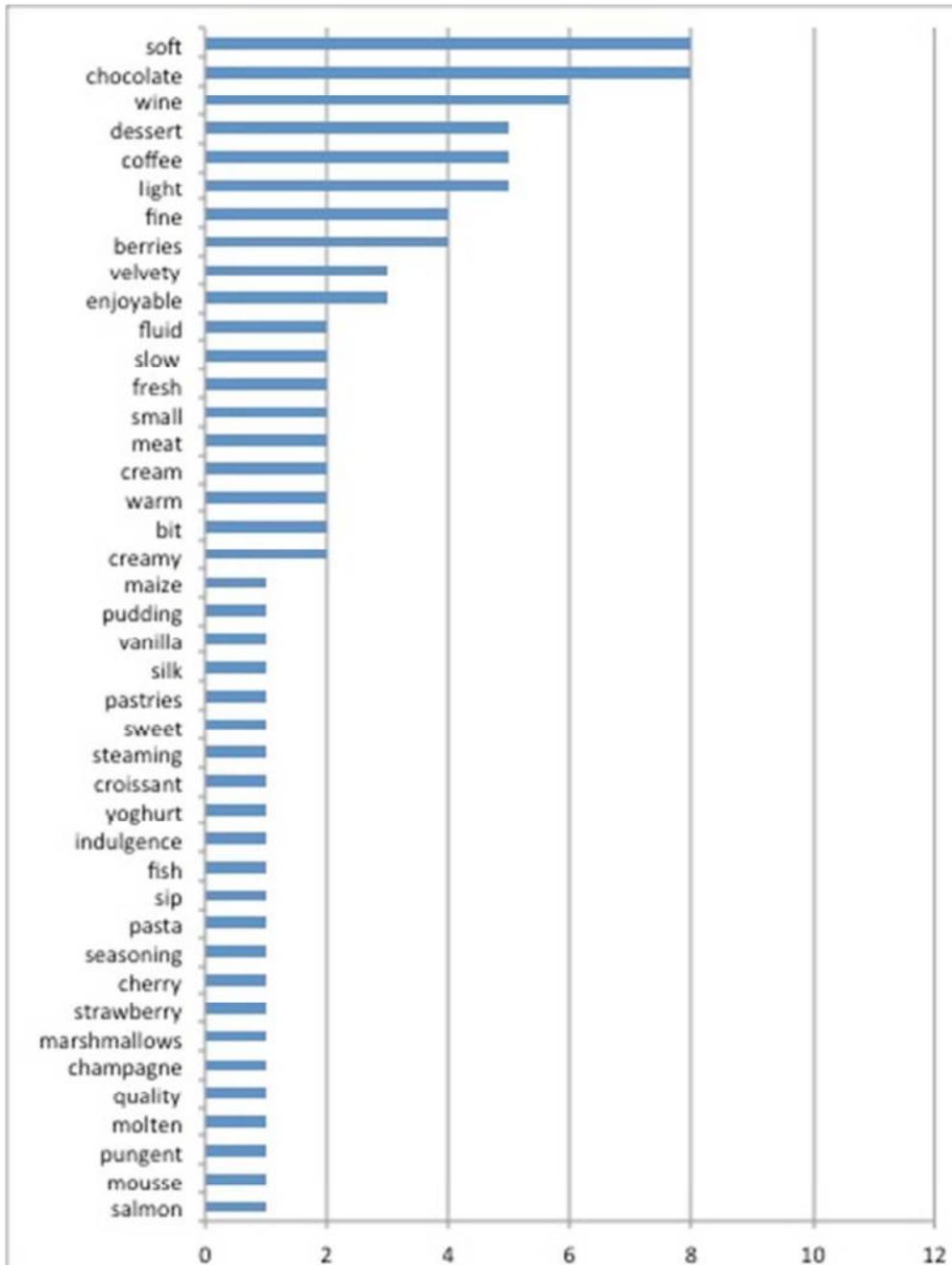
Ingredient	Total consumption (ml)/"Sweet" music	Total consumption (ml)/"Sour" music	Total sugar content (%)	Total organic acid content (%)
Honey	109	44	80	0
Mango juice	1350	450	10	<0.1
Pineapple juice	1000	650	30	0.6
Lemon juice	34	160	1.6	4.4
Grapefruit juice	750	1750	9	0.3
Orange juice	900	650	10	0.6

TABLE 4. The total consumption of ingredients with "sweet" and "sour" music. Sugar and organic acid contents (%) of ingredients as reported by Fineli® - Finnish Food Composition Database (Fineli).

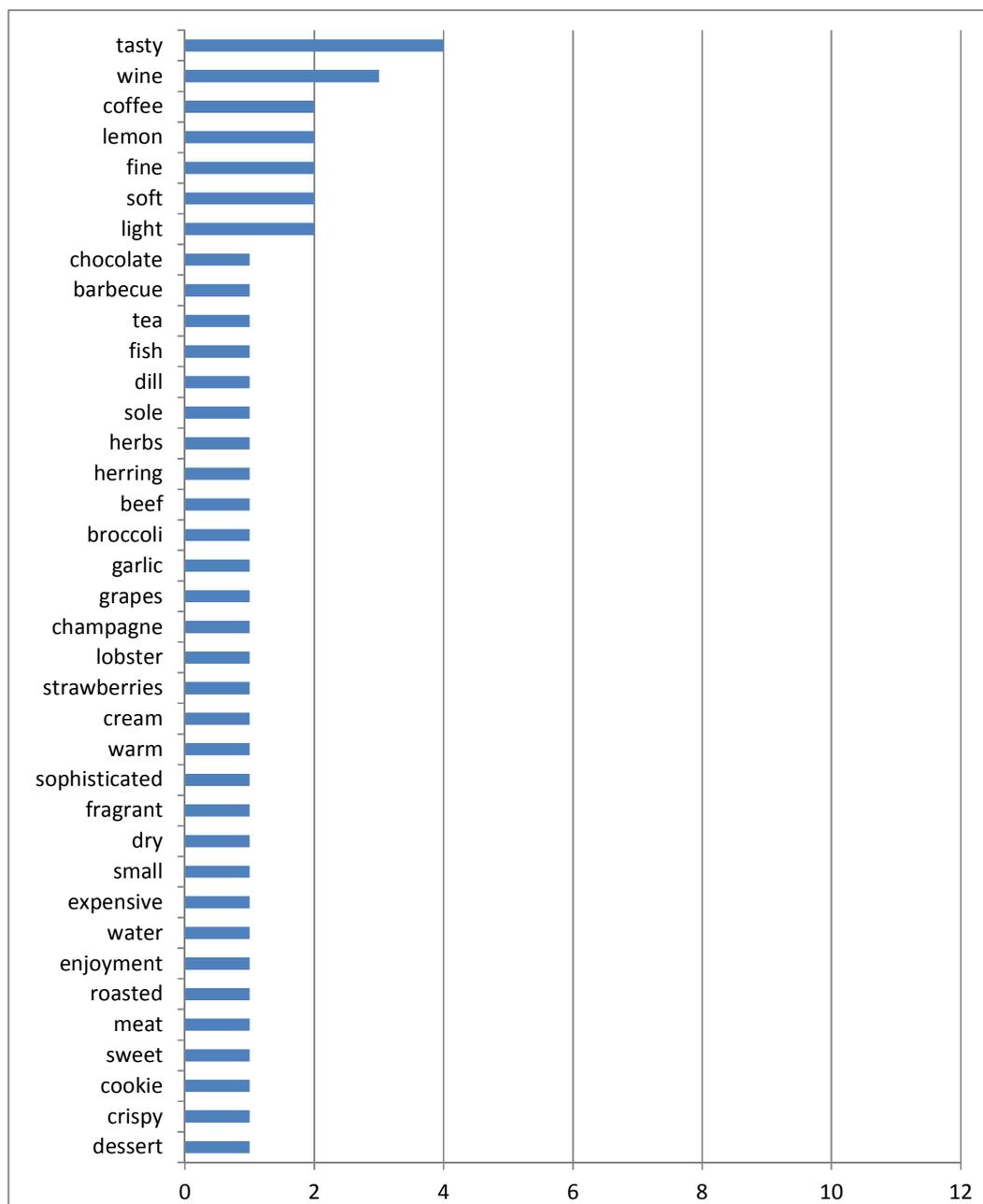
p-value	Sucrose	Glucose	Fructose	Total Sugars	Malic acid	Citric acid	Total Acids	Sugar:Acid Ratio
	p = 0.000	p = 0.096	p = 0.086	p = 0.007	p = 0.058	p = 0.000 ¹	p = 0.000	p = 0.000 ¹
Satie n = 18	47.1 ± 12.3 ^A	37.4 ± 9.1	39.4 ± 11.2	123.9 ± 26.2 ^A	1.4 ± 0.7	7.2 ± 1.3 ^A	8.6 ± 1.6 ^A	15.4 ± 6.1 ^A
Schumann n = 12	39.0 ± 9.8 ^{AB}	39.9 ± 12.2	43.1 ± 14.9	121.9 ± 34.9 ^{AB}	0.9 ± 0.4	7.4 ± 1.9 ^A	8.3 ± 2.1 ^A	15.7 ± 5.9 ^A
Ferneyhough n = 20	35.4 ± 9.7 ^B	32.0 ± 11.6	33.9 ± 13.2	101.2 ± 29.1 ^{AB}	1.2 ± 0.5	10.6 ± 3.4 ^B	11.8 ± 3.4 ^B	9.3 ± 3.4 ^B
Mesz n = 15	29.4 ± 7.3 ^B	31.7 ± 9.3	32.4 ± 9.9	93.6 ± 23.5 ^B	1.0 ± 0.4	10.9 ± 2.3 ^B	11.9 ± 2.1 ^B	8.3 ± 3.2 ^B

TABLE 5. The sugar and acid contents (g/l) of the drinks prepared in the “sweet” (Satie and Schumann) and “sour” (Ferneyhough and Mesz) music groups. The significance (p-value) of the differences between the groups (marked with letters A and B) was determined by ANOVA and the Tukey HSD post hoc test. The mean values and standard deviations (g/l) are reported in rows (e.g., 47.1 ± 12.3).

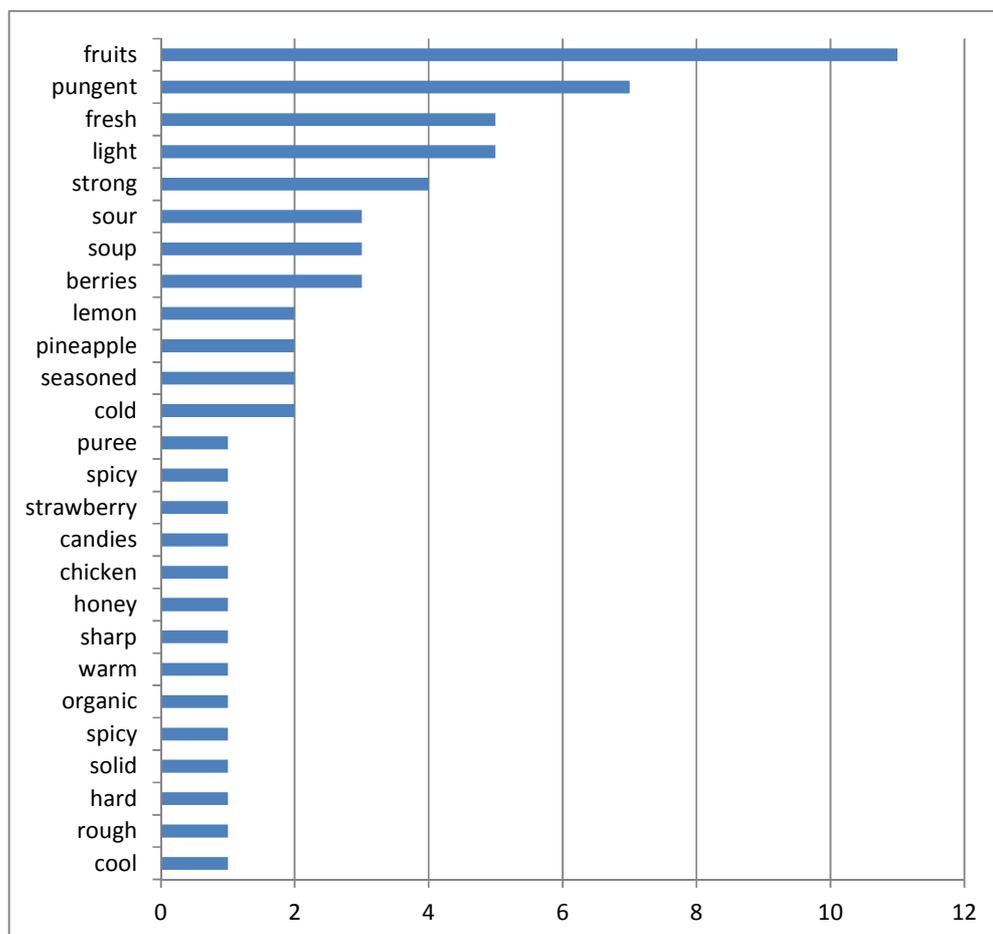
FIGURE 1 A-D. The frequencies of food-related associations in different experimental groups: A. “Sweet” music (Satie); B. “Sweet” music (Schumann); C. “Sour” music (Ferneyhough) and D. “Sour” music (Mesz). The words that the study participants used to describe their food-related associations when listening to the music are listed in vertical. The horizontal bars mark the frequency of the word. For example, in the group A., eight participants used the word ‘soft’, and five participants used the word ‘dessert’.



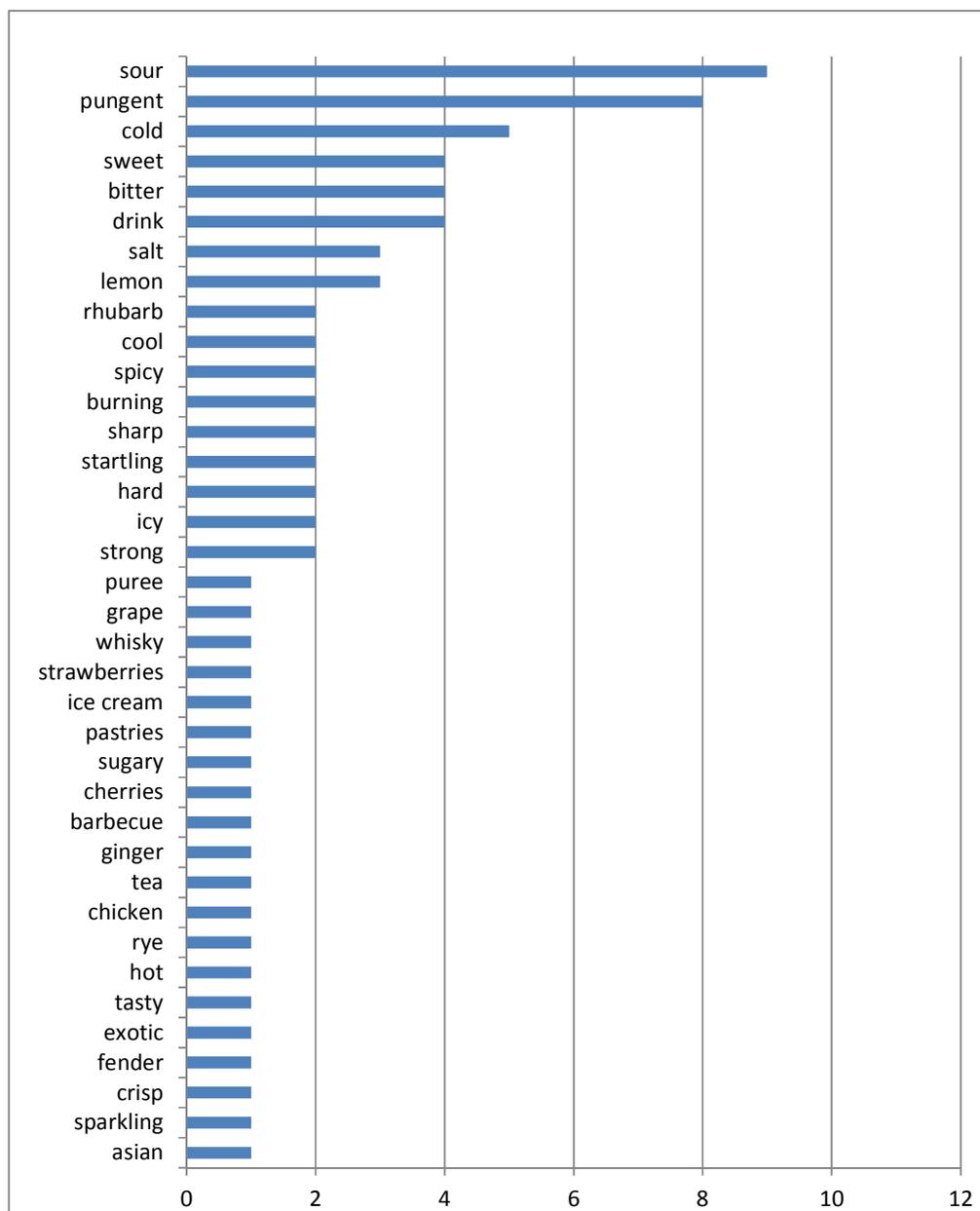
A. “Sweet” music (Satie), n=18



B. "Sweet" music (Schumann), n=12



C. "Sour" music (Ferneyhough), n=20



D. "Sour" music (Mesz), n=15