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Having a Drink with Tchaikovsky: The Crossmodal Influence of Background Music on the Taste of Beverages

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Abstract

Previous research has shown that auditory cues can influence the flavor of food and drink. For instance, wine tastes better when preferred music is played. We have investigated whether a music background can modify judgments of the specific flavor pattern of a beverage, as opposed to mere preference. This was indeed the case. We explored the nature of this crosstalk between auditory and gustatory perception, and hypothesized that the 'flavor' of the background music carries over to the perceived flavor (i.e., descriptive and evaluative aspects) of beverages. First, we collected ratings of the subjective flavor of different music pieces. Then we used a between-subjects design to cross the music backgrounds with taste evaluations of several beverages. Participants tasted four different samples of beverages under two contrasting audio conditions and rated their taste experiences. The emotional flavor of the music had the hypothesized effects on the flavor of the beverages. We also hypothesized that such an effect would be stronger for music novices than for music experts, and weaker for aqueous solutions than for wines. However, neither music expertise nor liquid type produced additional effects. We discuss implications of this audio-gustatory interaction.

Keywords

Crossmodal correspondences, multisensory perception, auditory-gustatory interaction, background music, wine, expertise

1. Introduction

When talking about the culinary delights we experienced on a vacation, we tend to describe not only the gustatory properties of food and drinks we consumed, but we likewise describe the romantic ambient light at sunset, the fantastic jazz combo that played in the background, and the heavy crystal

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glasses in which the wine was served. As impressed as we may feel by a gustatory experience, it appears difficult to properly separate it from other sensory input (e.g., Oberfeld *et al.*, 2009; Spence *et al.*, 2014). Having returned home, the souvenir bottle of wine may not taste nearly as well as it did on the vacation terrace. The same drink consumed at another place may taste sweeter, less bitter, or more harmonic. Environmental factors, such as haptics or noises, have been shown to influence gustatory experience; however, music has not yet been deeply investigated in this context. We first introduce the existing body of research on crossmodal correspondences (see Spence, 2011, for detailed discussion of the concept) in terms of auditory and gustatory perception, and then present our experiment on crossmodal effects of classical music.

1.1. Auditory Influences on the Perception of Food and Drink

In contrast to olfactory, visual, and haptic influences, the impact of auditory stimuli on food and drink-related variables has started to receive serious attention much later (see Knöferle and Spence, 2012, for a review). The first findings date back to Holt-Hansen (1968) who found that certain pitches of pure tones could be matched to certain flavors. The author's subjects tasted two brands of beer and had to select the pitch of a pure tone that was most 'in harmony' (Holt-Hansen, 1968, p. 60) with the flavor of the beer. Results revealed that the average frequency matched to regular Carlsberg beer was lower (510–520 Hz) than that matched to the stronger Carlsberg Elephant beer (640–670 Hz). A replication by Rudmin and Capelli (1983) involving non-alcoholic beer, grapefruit juice, hard candy, and dill pickles — beside Carlsberg beer — supported the original findings. Also, sweeter beer is matched with higher-pitch tones as compared to more bitter beer, as recently reported by Reinoso Carvalho *et al.* (2016a).

Not only is there evidence that tastes can be matched to sounds; there is also evidence that auditory stimuli can modulate gustatory judgments. Effects were found for the opening sound made by the packaging (e.g., Spence and Wang, 2015a; Spence *et al.*, 2011), for the sound produced by the product itself during consumption (e.g., Demattè *et al.*, 2014; Vickers, 1982; Zampini and Spence, 2004), in fact for any ambient sound, such as music, present while eating or drinking (e.g., Kantono *et al.*, 2016a; Reinoso Carvalho *et al.*, 2015; Spence *et al.*, 2011; Wang *et al.*, 2017a; Woods *et al.*, 2011).

As to the impact of ambient sounds and background music in the context of food and drink consumption, numerous dependent variables have been investigated, typically in the context of consumer research. For instance, subjects purchased more French than German wine if French accordion music was played, compared to German Bierkeller music (North *et al.*, 1999). Yeoh and North (2010) demonstrated an effect of music when choosing between two competing foods. Participants of Malay, Indian, and Chinese ethnicity had to choose between Malaysian and Indian food while Malaysian or Indian background music was played. They chose the food according to the ethnicity of the music (see also Zellner *et al.*, 2017). North and colleagues suggest that both effects may be due to cognitive priming (e.g., Baddeley, 1999). As to the influence of music volume, young beer drinkers were found to drink significantly faster when music was played at 88 dB, as compared to 72 dB (Guéguen *et al.*, 2008). Besides, music with fast rhythms prolonged patrons' time of stay and the number of consumed drinks (Milliman, 1986). The presence of music in general is connected with higher food intake compared with no music (Stroebele and Castro, 2006). The musical background can even modulate perceived food texture, such as creaminess of chocolate (Reinoso Carvalho *et al.*, 2017).

These results involving objective behavioral measures are mirrored by studies using subjective taste ratings. Spence *et al.* (2011) asked their subjects to taste two samples of the same bacon-and-egg-flavored ice cream while confronting them with the sound of sizzling bacon (congruent) vs. the clucking of farmyard chickens (incongruent). As the researchers had suggested, ratings of the relative strength of bacon flavor were higher in the congruent than in the incongruent condition. In a second experiment, pleasantness ratings of oysters were higher when consumed with a congruent ambient sound (sounds of the sea) than with an incongruent 'farmyard noises'-condition. Kantono *et al.* (2016b) reported the transfer of perceived pleasantness from music to chocolate ice cream and an enhanced judgment of sweetness when the background music was liked. In the same vein, Reinoso Carvalho *et al.* (2016b) showed that specifically designed soundtracks can modulate the perceived sweetness, sourness, bitterness, and alcohol content of beers. Inversely, professional musicians who had the task to express a certain basic taste in improvisational music, spontaneously employed consistent musical parameters for each taste (Mesz *et al.*, 2011). In a large-sample study, Spence *et al.* (2014) found a similar effect with wine. The same wine was perceived as fresher and less intense with background music that was composed to evoke the connotation of 'sour', as compared to music composed to sound 'sweet'.

Wine and music seem to have a certain commonality in terms of their impression on people, as people tend to agree that certain wines go well with certain musical pieces. For example, Tchaikovsky's string quartet No. 1 was judged to be most compatible with a heavy red wine, as opposed to lighter red and white wines (Spence *et al.*, 2013). In the same vein, subjects reported which musical pieces they thought were the best match for a given wine in a study by Wang and Spence (2015). To do so, they described wines in musical terms (Spence and Wang, 2015b, c). We took the opposite route and had subjects characterize music in terms of flavor attributes.

The studies described thus far let us suppose that auditory stimuli have an impact on taste perception, even if sounds are not directly related to properties of the product itself. Adrian North (2012) was interested in how far music stimuli containing an emotional connotation may work in a symbolic way, influencing the perception of taste by transferring emotional connotations from music to drink. As his study is of particular interest for the research reported here, it is presented in detail.

North (2012) investigated whether music would lead to the distortion of the gustatory perception of a red and a white wine in accordance with the emotional connotation of the concurrent musical piece. The music he employed was classified in a small pilot experiment with the help of a forced-choice design: ‘Just can’t get enough’ by Nouvelle Vague (characterized by participants as ‘zingy and refreshing’), ‘Carmina Burana’ by Carl Orff (‘powerful and heavy’), ‘Waltz of the Flowers’ from Tchaikovsky’s Nutcracker’s suite (‘subtle and refined’), and ‘Slow Breakdown’ by Michael Brook (‘mellow and soft’). In the main experiment, the researcher had 250 students taste a white or a red wine in conjunction with one of the above-mentioned musical pieces, respectively, in a between-subjects design. Participants rated the wines regarding each of the four double-term dimensions. For that purpose, an 11-point scale ranging from 0 (‘the wine definitely does not have this characteristic’) to 10 (‘the wine definitely does have this characteristic’) was used. They also rated their global liking of the wine from 0 (‘not at all’) to 10 (‘very much’). Subsequently, participants were to rate how much they liked the music and to indicate which of the four double terms, in their opinion, best described the music they had heard during the experiment. Results revealed a significant main effect of the audio condition, and post-hoc tests showed that mean ratings were highest when the congruent music was played. Wine was perceived as significantly more ‘powerful and heavy’ when accompanied by Carmina Burana and more ‘mellow and soft’ with Michael Brook.

1.2. Research Objective

We wanted to find out if the effect of music on taste is unidimensional in hedonic terms, or if more fine-tuned emotional characteristics of the music are transferred to the taste experience. Accordingly, we expanded on North’s experimental design. In our pilot experiment, music was not only categorized with a forced-choice questionnaire but evaluated in 16 specific dimensions, thereby we hoped to gain more insight into how the music was perceived. In the main experiment, we used the same questionnaires for taste ratings, and could thus compare the resulting music ratings with the taste ratings. We employed more than the four scales that North (2012) had used because we take double adjectives to be problematic, as they may not necessarily co-occur. For instance, a beverage can be perceived as ‘zingy’ but not necessarily ‘refreshing’. Thus, we added twelve single-adjective scales to the four double-term scales.

Apart from North’s (2012) double terms (‘zingy and refreshing’, ‘powerful and heavy’, ‘subtle and refined’, ‘mellow and soft’) and ‘global liking’, the questionnaire contained four basic taste categories (sour, sweet, bitter, and salty) in order to examine a possible difference between basic tastes and more complex aromas. Basic tastes appeared to show stronger associations with pitch than olfactory flavors (Crisinel and Spence, 2010a). As flavors cannot be examined without the consideration of olfaction (see Verhagen and Engelen, 2006, for a review), our third group consisted of terms from Henning’s (1924) olfactory prism: foul, floral, aromatic, and fruity. The fourth group was composed of emotional attributes with a possible relation to musical parameters, i.e., lively, gloomy, harmonic, and light, which was particularly important for examining if emotional connotations carry over from music to taste ratings.

We believed that the application of two (rather than four) different musical backgrounds would be sufficient to reveal the influence of music on taste judgments, so we used the two pieces of classical music that were most contrasting on the scales listed above. Unlike North (2012), we considered both basic taste samples and more complex aroma samples as gustatory stimuli (cf. Crisinel and Spence, 2010a), i.e., a sugar solution (sweet) and a citric acid solution (sour) were served in addition to red wine and white wine. Due to their simplicity and the lower chance of being confused with other flavors, basic tastes might be immune to external influences while complex wine aromas may be less salient and more open to individual interpretation. Wine and classical music also both have an air of sophistication in the eyes of most people, which could have a supporting effect (cf. Areni, 1993; North *et al.*, 2016). We thus wanted to examine potential differences between complex aromas and basic taste dimensions in terms of susceptibility to auditory influence.

North (2012) retrospectively suggested to pay more attention to differences between the subjects’ individual perception of the music and their understanding of the emotional message. We followed his advice to use homogenous groups of participants (North, 2012, p. 299) and recruited musicians and non-musicians. According to the information reduction hypothesis (Haider and Frensch, 1996), experts might approach music differently than novices, experts being less susceptible to potential crosstalk between auditory and gustatory sensations. The underlying reasoning suggests that repeated practice of a task improves performance, that is, the more experienced we are, the better we can decide which information is required to perform the task. Because of their experience, musicians have a richer mental representation of audio-related information than non-musicians, which should allow them to recognize more easily when auditory information is relevant for the task and when it is not.

In a different domain, Krishna and Morrin (2008) found results to this effect when comparing subjects with an above-average need to touch objects, who were thus experts for haptic input whereas others were not. Taste ratings of the haptic experts were not influenced by non-diagnostic haptic cues whereas those of the non-experts were. This shows how experts can become immune to crossmodal effects.

For the present research, we pursued three hypotheses. First, we expected beverages to be rated differently according to the prevailing music condition. The audio effect on taste ratings should be semantically consistent with the characterization of the musical pieces as assessed in the pilot experiment. Second, we predicted the effect of music on taste perception to be smaller for aqueous solutions than for wines. Finally, we hypothesized that the crossmodal influence would be smaller for music experts than for novices.

2. Pilot Experiment to Select and Evaluate Music

The music stimuli were selected and evaluated in a pilot study in order to find two pieces of classical music that differ markedly. For the sake of comparing the results to North's (2012) study, we decided to use one of his music samples and then to select a noticeably different piece within the realm of classical music.

2.1. Method

2.1.1. Subjects

The pilot experiment was carried out via email with a pseudo-random sample of German students ($n = 11$) and non-students ($n = 7$). Eighteen subjects (7 males, 11 females) aged from 22 to 65 years (mean age = 34.11, SD = 15.44) returned the questionnaires. In terms of music experience, 10 subjects reported to play an instrument, seven of whom practiced on a weekly basis.

2.1.2. Design and Procedure

Participants listened to five classical music pieces [see Table 1(a)] and evaluated them on 17 different 11-point rating scales. These included a 'global liking' scale labeled from 0 to 10 (0 = 'I do not like the music at all'; 10 = 'I like the music very much') as well as 16 scales for the dimensions light, fruity, powerful and heavy, gloomy, aromatic, sweet, subtle and refined, sour, harmonic, salty, zingy and refreshing, foul, lively, floral, mellow and soft, and bitter [see Table 1(b)]. The latter were likewise labeled from 0 to 10 (0 = 'the music does not have this characteristic at all'; 10 = 'the music definitely does have this characteristic').

Table 1.
Pilot experiment: (a) The music pieces that had to be evaluated, (b) The labels of the rating scales with English translations in brackets. Pieces and labels marked with an * had been used by North (2012)

(a)

Composer	Title
Alban Berg	Three Pieces for Orchestra, Op. 6: No. III ‘March‘
György Ligeti	Concerto for piano and orchestra: I. Vivace molto ritmico e preciso
Carl Orff	Carmina Burana: ‘O Fortuna’*
Igor Fyodorovich Stravinsky	Scherzo Fantastique, Op. 3
Pyotr Ilyich Tchaikovsky	The Nutcracker: ‘Waltz of the Flowers’, Op. 71, Nr. 13*

(b)

Basic tastes	Henning’s odor terms	Musical attributes	North’s double terms
Süß (sweet)	Faulig (foul)	Spritzig (lively)	Lebhaft und Erfrischend (zingy and refreshing)*
Sauer (sour)	Blumig (floral)	Düster (gloomy)	Kraftvoll und Schwer (powerful and heavy)*
Salzig (salty)	Würzig (aromatic)	Harmonisch (harmonic)	Fein und Raffiniert (subtle and refined)*
Bitter (bitter)	Fruchtig (fruity)	Leicht (light)	Weich und Sanft (mellow and soft)*

2.2. *Results and Discussion*

North (2012) had used among others the ‘Waltz of the Flowers’ by Tchaikovsky and ‘Carmina Burana’ by Orff. Tchaikovsky’s ‘Waltz of the Flowers’ differed most markedly from three newly introduced contemporary music pieces by Berg, Ligeti, and Stravinsky, as established by several multivariate analyses of variance (MANOVA). The ‘Waltz of the Flowers’ scored highest on ‘global liking’ ($M = 7.72$, SD $= 1.78$); thus we selected this piece for the main experiment. To find the second auditory stimulus among the above-mentioned new pieces, MANOVAs with within-subjects factor ‘music’ and between-subjects factors ‘music expertise’ and ‘gender’ were calculated, comparing Tchaikovsky with each of the other pieces. Results showed that Alban Berg’s ‘Three pieces for orchestra (March)’ differed significantly on the highest number of dimensions (14 out of 16, see Appendix, Table A1, for statistical values). Univariate analysis of variance (ANOVA) showed that Berg and Tchaikovsky differed strongly in ‘global liking’ [$F(1, 14) = 18.03$, $p = 0.01$]. We concluded that Berg and Tchaikovsky were perceived as most different among all pieces.

Compared to the ratings in North's (2012) pilot study, 'Waltz of the Flowers' was rated somewhat differently here. His subjects ($n = 5$) classified it as 'subtle and refined', whereas in our study this double term merely received the fourth-highest rating ($M = 7.00$, SD = 2.401), after 'harmonic' ($M = 8.50$, SD = 1.465), 'zingy and refreshing' ($M = 7.78$, SD = 1.833), and 'light' ($M = 7.22$, SD = 2.045). We assume that this difference occurred due to the different response schemes (rating scales vs. forced choice). Our results provide the basis for the main experiment.

3. Main Experiment to Determine Potential Effects of Music on Taste

The two selected musical pieces from the pilot experiment were used as auditory background to test the crossmodal influence of music on taste perception. The flavors of our different beverages had to be characterized with each of the music backgrounds.

3.1. Method

3.1.1. Subjects

A total of 118 subjects participated in the experiment. Three of them had to be excluded from the sample because of errors during the experimental procedure. The remaining 115 subjects (44 male, 71 female) were aged from 17 to 66 years (mean age = 25.55, SD = 6.69) and included both university students ($n = 88$) and non-students ($n = 27$). A considerable number of participants ($n = 51$) were psychology students recruited via a mailing list, others were contacted in local symphony orchestras and sports clubs. Slight impairment of the senses was noted in a few subjects [smokers ($n = 7$), cold sufferers ($n = 2$), hearing-impaired persons ($n = 2$)]. As they felt comfortable with the task, the respective subjects were not excluded from the sample. We later confirmed by visual inspection that their results did not constitute obvious or worrisome outliers. Thus, all subjects were included in the analyses. Comparing the samples of the pilot experiment and the main experiment, subjects were on average 8.56 years older and had a higher educational level (approx. twice as many had university degrees) in the pilot experiment. A univariate ANOVA showed that the samples did not differ significantly in gender [$F(1, 131) = 0.00$, $p = 0.960$], professional status [$F(1, 131) = 1.942$, $p = 0.166$] or music expertise [$F(1, 131) = 0.05$, $p = 0.830$].

We assigned the subjects to three different groups based on the self-assessed music expertise, experts ($n = 38$), novices ($n = 38$) and in-betweeners ($n = 39$). All experts said they were at least 'somewhat' musical, had been involved in music 'a lot' throughout their lives, and played an instrument at least at an 'advanced level'. Novices described themselves as maximally 'somewhat' musical and they did 'not at all' play an instrument or only at 'beginners' level', or for 'less than one year', or had last played 'more than 10 years ago' (please find classification criteria in the Appendix, Table A2). All participants who did not fulfill one of these two sets of criteria were categorized as in-betweeners and excluded from the testing of the third hypothesis, which aimed at showing a group difference between music novices and experts. Univariate ANOVAs showed that novices and experts did not differ in terms of age [$F(1,73) = 0.33$, $p = 0.569$], gender [$F(1,73) = 1.63$, $p = 0.207$], or educational background [$F(1,72) = 2.93$, $p = 0.091$].

All participants were naïve to the aim of the study and informed consent was obtained before participation. They were informed that the experiment involved the consumption of alcohol.

3.1.2. Apparatus and Stimuli

The experiment took place at the Department of Psychology of the Johannes Gutenberg-Universität Mainz in a room equipped with two semi-closed cubicles. The cubicles (100 × 200 × 120 cm) were made of white boards and had an opening covered with a white curtain in the rear. They were illuminated with LED panels hanging from the back wall (LED Panel RGB DMX 230 V, Eurolite; color mode: white). In each cubicle there was one chair in front of an integrated table with the back rest against the open side of the cubicle. In order to evoke a restaurant-like atmosphere, the tables were prepared with a red place mat, a tea light (not lit) and a cream-colored napkin. Furthermore, each cubicle was equipped with a customary glass of tap water, a pen, an information sheet, and a set of eight beverage rating-questionnaires. Digital sound files (wav) were played on a Dell PC (GX240 MT; OS: Windows XP) or an Apple PowerBook (G4) placed outside the cubicles with circumaural closed-back headphones (K272 HD, AKG or HFI-780, Ultrasone). All audio files were precisely measured and brought to the same equivalent continuous sound level (69.4 dB) for both sets of hard- and software. As the original duration of the pieces was too short for the tasting of all beverages, both pieces were repeated once and cut off after a total of 11 min (editing software: Audacity 2.0.3).

There were four different beverages for participants to taste: red wine, white wine, sugar water and citric acid solution. Two types of wine, a dry Riesling (Allendorf Festival 2012; Qualitätswein) and a dry Dornfelder (Allendorf Dornfelder 2012; Qualitätswein) were used, each bottle for a maximum of two days after being opened, such that the flavor of the wine was held as constant as possible throughout the experiment. In order to obtain the two solutions, sugar and citric acid were diluted in still water of the same brand (Gerolsteiner Naturell; 1-liter glass bottles) in a concentration of 20 g sugar/liter and 1 g citric acid/liter. The solutions were strong enough to produce a recognizable taste, but faint enough to not risk the provocation of disgust or nausea. We did not attempt to match the concentration of the uniflavored solutions to that of the multiflavored wines. Fifty ml of the respective beverages were served in black opaque wine glasses (Sensus black, Schott Zwiesel, Germany; volume = 299 ml) to avoid the influence of any color differences among the liquids. The beverages were kept in a customary fridge at approximately 9° C in order to control the temperature and keep it constant.

3.1.3. Design and Questionnaires

A full factorial between-subjects design was used. Every participant tasted each of the four beverages in conjunction with each of the two types of background music. Within every musical unit, the order of the beverage samples was randomized to rule out potential confounds from order effects. Presentation order of the musical pieces was counterbalanced (55 subjects started with Tchaikovsky, the others with Berg). The beverage rating questionnaires started with the 'global liking' scale, followed by rating scales of the 16 dimensions, as had the music ratings in the pilot experiment. Subsequent to the beverage ratings, the music was rated. Demographic data were assessed, including questions on experience with music, degustation, and wine. Moreover, participants were asked to guess how many different beverages had actually been served.

3.1.4. Procedure

At the beginning of the experiment, participants (at most two at a time) were told that the experiment involved the tasting of eight beverages and the completion of various questionnaires. They were to rate the beverages independently and as spontaneously as possible. Participants were told to try to feel at ease and to imagine a restaurant-like atmosphere in which they would listen to music via headphones in order to avoid distraction by ambient noise. Information about the purpose of the music was withheld, as well as the fact that the eight beverages corresponded to the same set of four beverages served twice. The experimenter asked the subjects not to look into the glass, and told them to drink a sip of water after every beverage in order to neutralize remnants of the beverage.

Participants took a seat (one person per cubicle) and were given the time to read the instructions again. They put on the headphones and listened to the music for one minute behind the closed curtain. Meanwhile, the investigator filled the glass and then served the first beverage. Participants had 2.5 min to taste and rate each beverage and decided freely if they wanted to drink the beverage or if they wanted to spit it out after having explored its flavors. They could drink as much as they wanted out of the glass. Beverages were served at fixed points in time, such that every participant gave the rating at equivalent moments within the music clip. Participants filled in one questionnaire per beverage and turned it over after completion. They drank a sip of mineral water after every sample. After eight beverage ratings, each music piece was played again for 2 min and both were rated on the music questionnaire that had already been used in the pilot experiment. Finally, participants filled out the demographic data questionnaire, followed by a debriefing. Altogether, the experimental session lasted approximately 45 min.

3.2. Results

3.2.1. Music Ratings: Comparison of Pilot Experiment and Main Experiment

As to music ratings, similar patterns were found for the different dimensions and ‘global liking’ (see Fig. 1), suggesting that consistency between the current and the pilot experiment is very high.

3.2.2. Beverage Ratings: Impact of Background Music on Perception of Taste

In order to test whether beverage ratings were influenced by background music, mean beverage ratings with the Berg and the Tchaikovsky background were compared. To examine ‘global liking’, a 2 (music) × 4 (beverage) repeated measures ANOVA (rmANOVA) with between-subjects factors ‘gender’, ‘music order’ and ‘music expertise’ was calculated. Degrees of freedom were Huynh–Feldt-corrected for reasons of sphericity violation. Between-subjects factors did not reach significance. There were significant main effects for ‘music’ [$F(1, 110) = 10.68$, $p = 0.001$], and ‘beverage’ [$F(2, 330) = 18.45$, $p \leqslant 0.001$]. The interaction of ‘music’ × ‘beverage’ was not significant

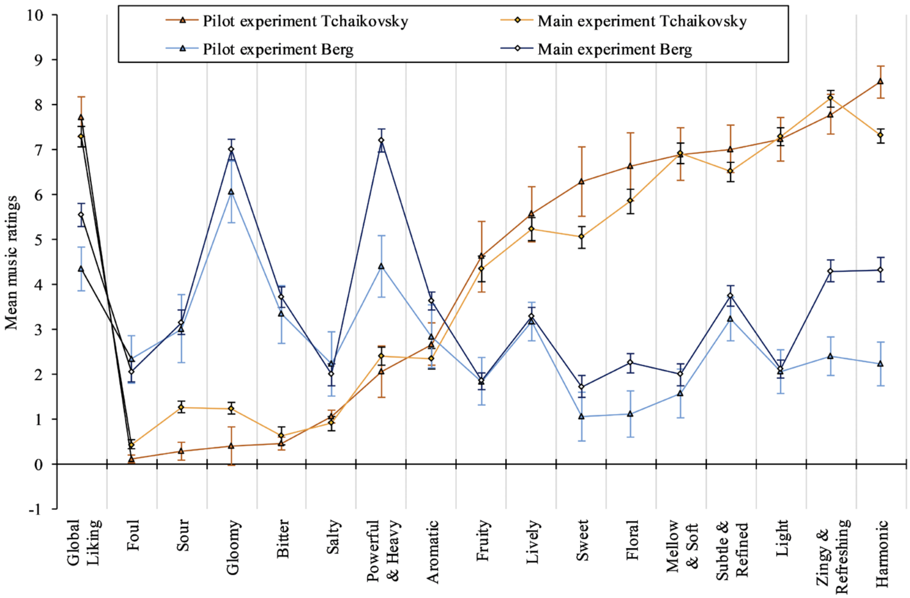

Figure 1. Music ratings in pilot and main experiment. Data points represent mean ratings of the musical pieces (vertical axis) for ‘Global Liking’ and the different content dimensions (category axis). Error bars show ±1 standard error of the mean (SEM).

[$F(3, 330) = 0.314$, $p = 0.82$]. 'Global liking' of the beverages was significantly higher in the Tchaikovsky ($M = 4.45$, SD = 1.39) as compared to the Berg condition ($M = 4.04$, SD = 1.32).

To test the effect of background music on the 16 dimensions, a 2 (music) × 4 (beverage) MANOVA on the beverage ratings was calculated, again with the between-subjects factors 'gender', 'music order' and 'music expertise'. The latter three were not significant. There was a significant main effect for 'music' [Pillai's trace = 0.29, $F(16, 88) = 2.24$, $p = 0.009$], as well as for 'beverage' [Pillai's trace = 1,94, $F(48, 888) = 33.94$, $p < 0.001$]. 'Music' × 'beverage' interaction did not reach significance [Pillai's trace = 0.18, $F(48, 888) = 1.18$, $p = 0.196$]. As to univariate effects of the factor 'music', nine out of 16 dimensions reached significance at the $p = 0.05$ level (see Appendix, Table A3, for statistical values). Figure 2 shows mean ratings for each beverage with both musical backgrounds in a radar plot.

We examined whether the significant main effect of background music on beverage ratings took the desired direction, which means that those dimensions that scored higher for Berg music than for Tchaikovsky in the pilot experiment should likewise do so here. For the purpose of illustration, mean differences ($\text{Mean}_{\text{Berg}} - \text{Mean}_{\text{Tchaikovsky}}$) on the significant scales for both music and beverage ratings are presented in Fig. 3. It is apparent that differences between beverage ratings show the same pattern of positive and negative values as do differences between music ratings.

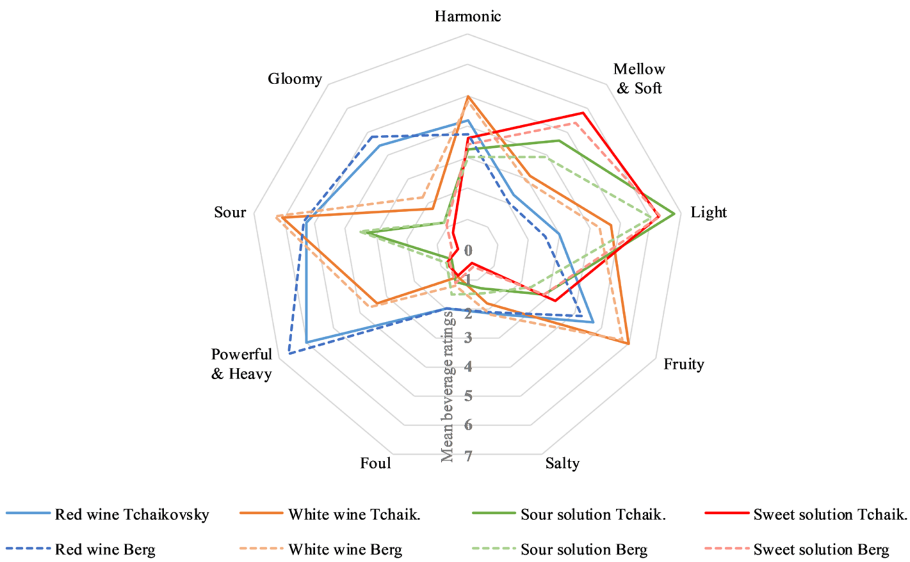

Figure 2. Mean beverage ratings separated by beverage and background music. Only those dimensions are depicted for which there was a significant main effect of 'music'.

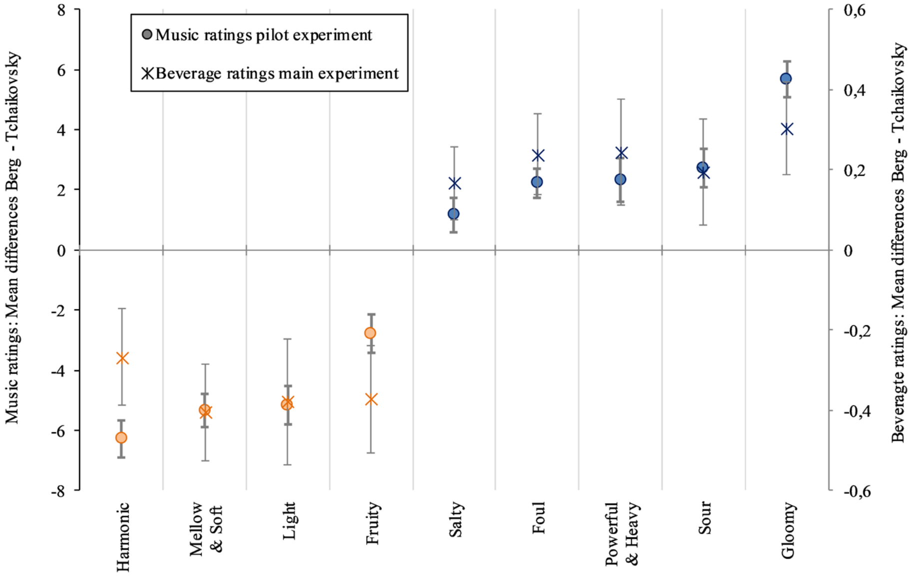

Figure 3. Mean differences between Berg and Tchaikovsky conditions ($\text{Mean}_{\text{Berg}} - \text{Mean}_{\text{Tchaikovsky}}$) for beverage and music ratings. Only those dimensions are depicted for which beverage ratings showed a significant main effect of 'music'. Differences > 0 represent higher ratings for Berg; differences < 0 represent higher ratings for Tchaikovsky. Beverage ratings are displayed on a secondary scale for clarity. Error bars show ± 1 SEM.

We furthermore examined the hedonic value of the ratings. If music type changes the taste ratings such that positive flavors differ favoring the Tchaikovsky piece, negative flavors the Berg piece, and neutral flavors produce no differences, then it is possible or even likely, that the hedonic quality of the music carries over to the entire gamut of taste qualities. This seems to be the case to a relatively large extent. A small inquiry with four unbiased subjects (two men, two women) confirmed that there were six positively connoted (fruity, sweet, subtle and refined, harmonic, zingy and refreshing, mellow and soft), three negatively connoted (gloomy, foul, bitter), and seven ambiguous terms (light, powerful and heavy, aromatic, sour, salty, lively, floral). Descriptive data in Fig. 4 show that all positive attributes were rated higher for Tchaikovsky (three significantly so) and all negative attributes were rated higher for Berg (two significantly so). Out of the ambiguous terms, four were rated higher for Tchaikovsky, and three for Berg (two significantly so).

The question how many different beverages participants thought they had tasted was answered with an average number of 4.92 different beverages (min $= 2$, max $= 8$, SD $= 1.52$).

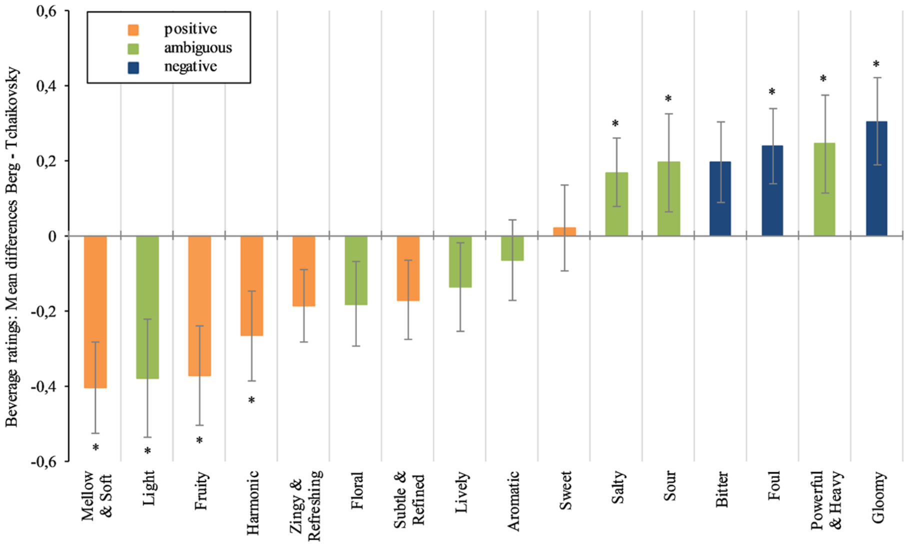

Figure 4. Mean differences between Berg and Tchaikovsky conditions ($\text{Mean}_{\text{Berg}} - \text{Mean}_{\text{Tchaikovsky}}$) for beverage ratings. Different colors show the hedonic connotation of the items. Asterisks show significant main effects of the factor ‘music’ with $p < 0.05$. Error bars show ± 1 SEM.

3.2.3. Beverage Ratings: Differences Between Wines and Solutions

To test if the influence of music on beverage ratings was different for solutions compared with wine, first both types of wine (red and white) as well as both solutions (sweet and sour) were grouped to form two categories of beverage type (wines vs. solutions). Interaction between ‘music’ and ‘type of beverage’ was examined. Concerning ‘global liking’, a 2 (music) × 2 (type of beverage) rmANOVA was calculated with ‘gender’, ‘music order’ and ‘music expertise’ as between-subjects factors. Main effects for ‘music’ [$F(1, 110) = 10.68$, $p = 0.001$], and ‘type of beverage’ [$F(1, 110) = 25.53$, $p < 0.001$] remained significant, whereas the interaction ‘music’ × ‘type of beverage’ did not reach significance [$F(1, 110) = 0.473$, $p = 0.493$]. Neither of the between-subjects factors approached significance.

With regard to the 16 dimensions, all relevant multivariate effects reached significance at the $p = 0.05$ level in a MANOVA with the known between-subjects factors: ‘music’ [Pillai’s trace = 0.28, $F(16, 88) = 2.18$, $p = 0.011$], ‘beverage’ [Pillai’s trace = 0.93, $F(16, 88) = 73.36$, $p \leqslant 0.001$] and ‘music’ × ‘type of beverage’ interaction [Pillai’s trace = 0.25, $F(16, 88) = 1.82$, $p = 0.041$]. Univariate interactions of ‘music’× ‘type of beverage’ reached significance at the $p = 0.05$ level for two out of 16 dimensions: ‘powerful and heavy’ [$F(1, 103) = 5.26$, $p = 0.024$], and ‘lively’ [$F(1, 103) = 4.71$,

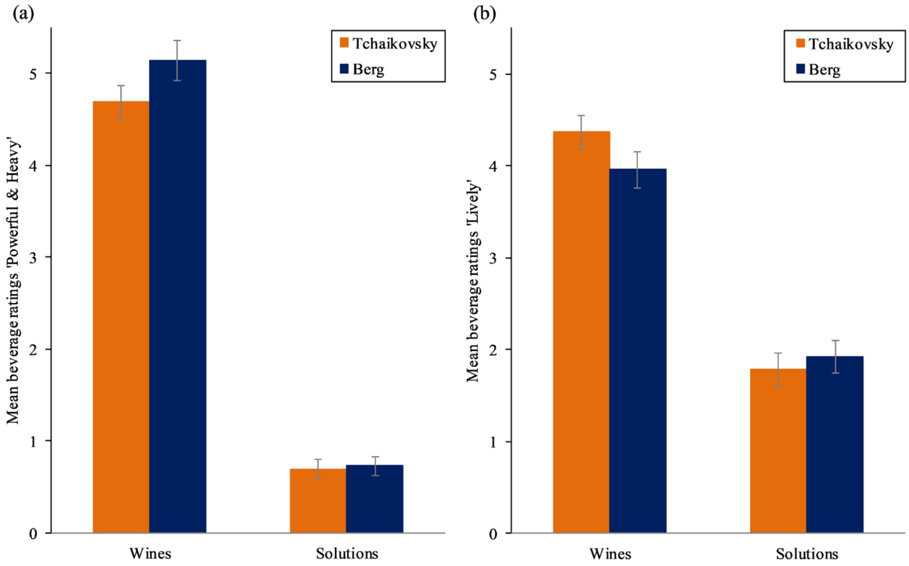

Figure 5. Means of beverage ratings per type of beverage for significant dimensions (a) 'powerful and heavy' and (b) 'lively'. Error bars show ±1 SEM.

$p = 0.032$]. Figure 5 shows the mean ratings of those two dimensions. Differences between the musical conditions were larger for wines than for solutions.

3.2.4. Beverage Ratings: Influence of Music Expertise

To show the influence of music expertise on the effect of background music on taste ratings, a reduced sample ($n = 76$, excluding in-betweeners) was used for analysis. The two groups were compared conducting a 2 (music) × 4 (beverage) ANOVA for 'global liking' and a 2 (music) × 4 (beverage) MANOVA with between-subjects factors 'gender', 'music order' and 'music expertise' for the 16 dimensions. For the 'global liking' scale there were significant main effects for both 'music' ($p = 0.002$) and 'beverage' ($p \leqslant 0.001$), but no significant interaction 'music' × 'expertise' ($p = 0.236$). The MANOVA did not reveal any effect of music expertise either ($p = 0.592$ for 'music' × 'music expertise'), however, there were significant multivariate effects for 'music' × 'beverage' ($p = 0.015$) and, interestingly, for 'beverage' × 'expertise' ($p = 0.007$).

4. Discussion

In the present study, we have investigated the potential influence of music on the taste of different beverages with regard to different levels of music expertise. Background music had previously influenced general liking and ratings of flavor categories of beverages described with the combination of two adjectives (North, 2012). We tested if the intersensory crosstalk goes beyond this general effect to the extent that it is reflected in specific semantic flavor categories which subjects attribute to beverages. This was indeed the case. Our results reveal that the musical impact on taste ratings amounts to the transferal of semantic musical connotations to the beverage. Music expertise was neither necessary nor disturbing for this effect.

We had entertained three hypotheses:

1. Beverages should be rated differently according to the prevailing auditory background condition, and these audio effects on taste should be semantically consistent with the characterization of the musical pieces assessed independently, as done in the pilot experiment.
2. We expected the effect of music on taste perception to be smaller for aqueous solutions than for wines.
3. We believed that the influence of music on taste perception would be smaller for music experts than for novices.

1. We showed that participants liked the wine more when the music they liked better was played, which confirms that emotional associations are relevant when it comes to wine–music matches (cf. Wang and Spence, 2017). We furthermore showed that participants perceived the taste of the beverages consistently with the characteristics of the music. In other words, beverages were judged to be more ‘floral’ when the more ‘floral’ piece of music was played and they were perceived to taste more ‘bitter’ when the more ‘bitter’ piece was played. This result is consistent with and elaborates upon previous research showing that auditory stimuli can have an impact on gustatory perception (e.g., Knöferle and Spence, 2012). It is also in agreement with outcomes indicating a systematic alteration of taste judgment by specifically designed soundscapes (Crisinel *et al.*, 2012). Finally, the findings are perfectly in line with and qualify North (2012), which will be discussed later. Not only did rather abstract attributes such as ‘harmonic’ and ‘powerful and heavy’ show an effect, but ratings on terms describing odors and basic tastes were influenced as well, which corresponds to what Crisinel *et al.* (2012) found in their study. The effect was stable for all groups of dimensions (basic taste words, odor terms, music attributes, North’s double terms). On the one hand, this shows that the specific emotional characteristics (music attributes, North’s double terms) of the music do carry over to corresponding experiences of aroma. On the other hand, we found evidence that the latter connection exists not only via emotionally charged particularities, but also more specifically and directly via the reflection of one sensory modality (basic tastes, odor terms) in the perception

of another. However, as ratings on the ‘global liking’ scale for the musical pieces were significantly higher for Tchaikovsky than for Berg, it stands to reason to consider a rather straightforward hedonic mechanism that transfers the hedonic connotation of the terms between music and beverage ratings. Indeed, positively connoted terms (e.g., ‘harmonic’, ‘mellow and soft’) gained higher ratings with Tchaikovsky’s and negatively connoted terms (e.g., ‘foul’, ‘gloomy’) gained higher beverage ratings with Berg’s music. Still, this interpretation does not sufficiently explain the effect, as not all significant attributes show clear hedonic tendencies and can be considered neutral (e.g., ‘powerful and heavy’, ‘light’). Thus, the crossmodal effects do include but cannot be reduced to a simple hedonic effect. To our knowledge, it is the first time that specific sweetening, souring and bittering effects of music have been demonstrated for music that was not deliberately composed to match particular tastes (cf. Wang *et al.*, 2017b). These findings are in line with insights about consonant sounds enhancing sweetness and dissonances enhancing sourness ratings (Wang and Spence, 2016, see also Kontukoski *et al.*, 2015), as our wine was judged more sour with Berg’s rather dissonant music than with the consonant ‘Waltz of the Flowers’. Moreover, the fact that subjects did not recognize that they drank the same set of four beverages twice, emphasizes the strong distorting influence of the music.

The described findings could reflect a universal synesthetic experience. However, this is unlikely, as experts should have overcome such associations (see Spence and Wang, 2015b, who arrive at a similar conclusion for different reasons). Alternately, applying the idea of cognitive priming theory (e.g., Baddeley, 1999), we can assume that listening to background music leads to cognitive priming of the respective emotional connotation. Subjects would thus be more likely to give a higher rating for the corresponding item when they judge the taste of a beverage. As proposed by North and Hargreaves (2008), music can raise the salience of certain schemata that are then more probable to be found in other contexts, for instance, when it comes to choosing and purchasing products. We can easily transfer this idea to the inter-sensual relationship between music and taste. Another possible explanation is that effects are attributable to the recognition heuristic, as proposed by Yeoh and North (2012) in their research about brand preference. The heuristic states that a known alternative will be chosen over the unknown one, in other words “the simple decision rule is to choose the recognized object” (Goldstein and Gigerenzer, 2002, p. 88). In order to be able to make a choice between two unknown alternatives, subjects would unconsciously search for something they recognize in order to facilitate their decision. For our scenario, this means that once a given flavor is found in the music, it is then also chosen as an attribute for the taste of the beverage. Note that this explanation presupposes a semantic relationship between music and flavor attributes.

2. Our second question was whether the effect of music on taste ratings would be smaller for beverage samples with simple, one-dimensional tastes (sweet and sour solutions) as compared to beverages comprising rather complex, multidimensional aromas, which are more open to individual interpretation (e.g., wines). Contrary to our expectations, the analyses did not reveal a general difference between the two beverage types. Interestingly, for two out of 16 dimensions, namely ‘powerful and heavy’ and ‘lively’, the hypothesized effect was indeed found. In these cases, the correspondence between beverage ratings and music ratings was significantly higher for wines than for aqueous solutions. It is striking that the two attributes fit particularly well with typical characteristics of red wine (powerful and heavy) and white wine (lively), and indeed, for both scales the effect was stronger for the respective typical wine.

A more general difference between the types of beverages might surface with more refined experimental methods. For example, a further diversification of taste samples with several white and red wines, and more than two different aqueous solutions might be helpful, or one could administer solutions of stronger taste. The aqueous solutions were perceived as rather weak and “water-like” (comment by several subjects) compared to the wines. The solution of citric acid, especially, had a rather low concentration in order not to make it unpleasantly sour. We may have been too cautious in that respect. As the initial purpose of the solutions was to provide beverage samples with simple and easily recognizable taste, one might increase the concentration until clear sweet or sour tastes become salient. However, our results are in line with findings by Knöferle *et al.* (2015), showing that basic taste properties can be systematically encoded into musical space parameters.

3. We did not find group differences between music experts and novices, i.e., expert taste ratings were as susceptible to background music as were novice ratings. Thus, we could not show that expertise overcomes or reduces crossmodal distortion of aroma judgments. However, this result is in line with findings showing that both wine experts and novices are susceptible to acoustic influences on taste evaluation (Wang and Spence, 2018). Other than anticipated, there was a difference between experts and novices in terms of perception of beverages regardless of background music. Music experts were better able to differentiate between beverages in general. It seems that sensory sophistication in the auditory domain is correlated with gustatory discrimination ability.

The missing group effect cannot be explained by information reduction theory (cf. Haider and Frensch, 1996) in this context. It is, furthermore, not in line with the assumption that sensory experts are less susceptible to crossmodal associations, as found by Krishna and Morrin (2008) for haptic experts. Deviating results might be due to different classification methods of expertise. In the present research, we tried not to misclassify potential experts just because they were not actively playing their instrument at the time of the experiment. On this account, most of the categorizing criteria were based on subjective measures and global questions (e.g., ‘How well do you play?’). As experts answered rather modestly and novices tended to be more self-confident in terms of their musicality, many participants ended up at some point in the middle of musical and non-musical categories. It is thus conceivable that a larger sample or a precise measure of expertise would have revealed an effect. However, the non-existent group differences fit with what Crisinel and Spence (2010b) found when they used a version of the implicit association test in order to find out if pitch was associated with basic tastes. Here, music experts and novices both revealed such associations. It would be interesting to have a differential look at wine experts and novices. However, in our sample there were not enough wine experts for analysis.

Finally, we briefly want to address a potential criticism that could be levied by believers in a conceptual separation of perception and judgment. They might argue that in our study, music did not alter taste perception, but merely provoked a shift in judgment criteria (cf. Firestone and Scholl, 2016). This may well be the case; however, we take conscious perception to necessarily include a judgmental component when subjects are asked to rate flavors. Thus, we prefer an integral account of perception and cognition, such as often associated with the concept of embodied perception (cf. Schnall, 2017). Interesting as such a debate might be, we consider it beyond the scope of this article.

In sum, the present research demonstrates that the music played in the background has a considerable impact on how we evaluate the flavor of food and drink. Moreover, we showed that the perceived taste and odor is modulated in a detailed way by carefully choosing the respective background music with special regard to its emotional connotations. When doing so, the semantic connotations conveyed by the music are almost perfectly mimicked by the beverage flavor experienced in the presence of the musical piece. Music experts fall prey to this crossmodal effect as well as do novices, and beverages need not be complex or sophisticated for music to take its effect on aroma perception.

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Appendix: Statistical Parameter Values

Table A1.
Pilot experiment: MANOVA for music ratings Tchaikovsky vs. Berg. Univariate effects of the factor 'music' (*: $p < 0.05$; **: $p < 0.01$)

Dimension	df	*F*	η^2	*p*
Light	1/13	61.949	0.827	<0.001**
Fruity	1/13	15.936	0.551	0.002**
Powerful & Heavy	1/13	6.745	0.342	0.022*
Gloomy	1/13	52.274	0.801	<0.001**
Aromatic	1/13	0.560	0.041	0.468
Sweet	1/13	59.947	0.822	<0.001**
Subtle & Refined	1/13	19.131	0.595	0.001**
Sour	1/13	16.620	0.561	0.001**
Harmonic	1/13	70.313	0.844	<0.001**
Salty	1/13	2.857	0.180	0.115
Zingy & Refreshing	1/13	98.796	0.884	<0.001**
Foul	1/13	12.705	0.494	0.003**
Lively	1/13	4.867	0.272	0.046*
Floral	1/13	42.690	0.767	<0.001**
Mellow & Soft	1/13	53.771	0.805	<0.001**
Bitter	1/13	6.817	0.344	0.022*

Table A2.
Classification criteria for music expertise. Scale intervals were [1] 'not at all'/'a little'/'somewhat'/'a lot' or [2] beginner'/'practiced'/'advanced'/'professional'

Expertise	Musicality self-assessment[1]	Involvement into music[1]	Instrument playing skills[2]
Experts	⩾ 'somewhat'	'a lot'	⩾ 'advanced level'
Novices	⩽ 'somewhat'	⩽ 'a lot'	'not at all' | 'beginners level' | 'more than 10 years ago' | 'for <1 year'

Table A3.
Main experiment: MANOVA for beverage ratings, univariate effects of the factor 'music' ($^{*}p < 0.05$; $^{**}p < 0.01$)

Dimension	df	F	η^2	p
Light	1/309	5.66	0.052	0.019*
Fruity	1/309	4.13	0.039	0.045*
Powerful & Heavy	1/309	4.32	0.040	0.040*
Gloomy	1/309	7.26	0.066	0.008**
Aromatic	1/309	0.00	0.000	0.993
Sweet	1/309	0.22	0.002	0.639
Subtle & Refined	1/309	2.56	0.024	0.113
Sour	1/309	4.06	0.038	0.046*
Harmonic	1/309	4.65	0.043	0.033*
Salty	1/309	5.79	0.053	0.018*
Zingy & Refreshing	1/309	3.47	0.033	0.065
Foul	1/309	5.45	0.050	0.022*
Lively	1/309	1.50	0.014	0.223*
Floral	1/309	1.30	0.012	0.257
Mellow & Soft	1/309	10.73	0.094	0.001*
Bitter	1/309	3.31	0.031	0.072