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Tasting in tune: The influence of music on taste evaluation under visual masking conditions

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ABSTRACT

This study investigates the effect of music on the evaluation of drinks presented unmasked (in open cups) or masked (in closed cups with opaque lids). Participants tasted five drink samples (varying in color and flavor) while listening to a sweet (SW) and a non-sweet (NS) soundtrack (within participants). Listening to the SW (vs. NS) soundtrack significantly increased the reported sweetness of drinks, whereas the NS (vs. SW) soundtrack increased sourness ratings. Moreover, participants liked the samples more and provided higher pleasantness ratings in the SW music condition. The visual masking manipulation (unmasked vs. masked) did not influence taste ratings. However, participants in the unmasked condition ($n = 65$) liked the samples more and rated them as more pleasant than those who tasted the masked samples ($n = 63$). Moreover, a significant interaction between music and visual masking suggested that music increased pleasantness ratings only when the samples were visible. In contrast, in the masked condition, pleasantness ratings remained nearly unchanged. These findings emphasize the potential of music for improving taste perception independently of visual cues. However, they also indicate that the use of opaque lids can worsen the hedonic experience and reduce some of the beneficial effects of music in a drinking situation.

1. Introduction

The way we perceive taste is subject to the influence of all senses. Commonly, taste refers to the subjective experiences people learn to describe as sweetness, saltiness, bitterness, sourness, or umami. At the most basic level, these sensations arise when chemical substances in the oral cavity interact with dedicated receptors. These discrete sensory inputs are later integrated within the brain, along with the olfactory and somatosensory inputs, to create the flavor experience (Small, 2012). From this standpoint, food perception may be considered multisensory, as the rich world of flavors we know emerges from the integration of distinct sensory modalities into unitary flavor percepts. In addition, other senses beyond taste and smell play significant roles in shaping food perception (Auvray & Spence, 2008; Spence, 2015). Factors such as the color of a plate (i.e., vision; Piqueras-Fiszman et al., 2012) or the ambient music in a dining environment (i.e., audition; Wang et al., 2017) can profoundly alter how individuals perceive flavors (Guedes, Garrido, Lamy, Cavalheiro, & Prada, 2023; Spence et al., 2019). However, it is crucial to differentiate between modalities that constitute the foundation of flavor perception – referred to as "constitutive" – and those that merely influence how flavors are experienced – referred to as "modulatory" senses (Skrzypulec, 2021; Spence, 2015). The role of each sensory modality in flavor perception might still be a matter of philosophical debate. Nevertheless, it seems unequivocal that flavor perception cannot be understood without reference to the contribution of the various sensory modalities. By the same token, human food consumption cannot be detached from the multisensory environment in which it occurs.

There are many circumstances when eating environments may be considered flawed from a multisensory perspective. For example, overly noisy atmospheres may compromise perception, not only by diminishing the felt intensity of taste or flavor attributes but also by worsening the hedonic experience (Bravo-Moncayo et al., 2020; Woods et al., 2011). Visual aspects may also set the wrong tone for eating, for example, when the color of the plateware is less suited to the food being served (Piqueras-Fiszman et al., 2012) or when the foods and drinks themselves are colored inappropriately (Zampini et al., 2007, 2008). The burgeoning research in the field of multisensory perception has allowed scientists and practitioners to better understand just how the multitude of sensory influences may contribute to shaping the eating experience

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and, crucially, how we may hope to optimize the multisensory atmosphere to achieve the best possible results (Spence, 2023; Spence & Piqueras-Fiszman, 2014).

Audition, though not traditionally emphasized in food perception research, has garnered increasing attention in recent years (Guedes, Garrido, Lamy, Cavalheiro, & Prada, 2023; Rodríguez et al., 2023). Overall, what individuals hear during consumption appears to have meaningful perceptual consequences. One relevant attribute to this effect is the crossmodal correspondences occurring between sounds and taste/flavor attributes. These correspondences describe how people often link seemingly unrelated characteristics of stimuli across different sensory modalities, such as associating sweet tastes with high-pitched sounds (Crisinel & Spence, 2009, 2010; Knöferle & Spence, 2012). Exposure to auditory stimuli (e.g., music) crossmodally associated with a given taste during consumption may contribute to enhancing the corresponding taste/flavor sensation in foods and drinks – a phenomenon popularized as "sonic seasoning" (Spence et al., 2019). For example, one recent study demonstrated that music more (vs. less) associated with the sweet taste increased the perceived sweetness of various foods (e.g., fruit, vegetables, sweets; Guedes et al., 2024). Interestingly, no such effect was observed when the same products were tasted with music that was perceived as more (vs. less) positive, thus emphasizing the explanatory role of crossmodal correspondences in sonic seasoning effects.

1.1. Tasting in the "dark"

In sensory science, visual masking is a common practice to limit the interference of visual cues on taste/flavor ratings. One can think of the illustrative example of olive oil tasting glasses, often seen in a characteristic cobalt-blue (International Olive Council, 2020). When the scope of the sensory evaluation does not include visual parameters, masking techniques are recommended to mitigate the influence these cues may have on other sensory aspects, such as taste or aroma. Some practices may include the use of opaque or colored containers, special lighting, or even the use of blindfolds (Fletcher et al., 1991; Sipos et al., 2021).

To date, several studies have examined the issue of visual masking on taste/flavor perception. Commonly, this research deals with the influence of product color on variables like taste evaluation or identification (Dubose et al., 1980; Johnson & Clydesdale, 1982; Maga, 1974; Morrot et al., 2001; Parr et al., 2003; Ross et al., 2008; Roth et al., 1988; Wang & Spence, 2019). Since color offers important cues regarding what participants may expect to taste, some studies have explored questions such as the ability to identify flavors when drinks are colored appropriately (e.g., a cherry-flavored drink colored red) compared to when they are presented in a less usual color, like green (Dubose et al., 1980). Other studies have shown, for instance, that enology undergraduates more frequently used red-wine descriptors to describe a white wine that was dyed red using an odorless substance (i.e., anthocyanin; Morrot et al., 2001), and even experts appear to be misled by a white wine that was colored to appear rosé (Wang & Spence, 2019).

While these examples generally allude to food color manipulations (such as shifting from an appropriate to a less appropriate hue), it is relevant to ask whether such changes are comparable to when visual cues are absent. Recently, one study found that visual deprivation could improve the perception of one taste attribute (Leszkowicz et al., 2023). Participants' sensitivity to five basic tastes was evaluated when blindfolded and with eyes open. While no differences were found for the other basic tastes, participants were able to detect sweetness earlier when blindfolded. This research, initially conducted with European participants, was subsequently replicated with a sample from Southeast Asia. The findings of this second study mirrored those of the first, showing similar results, particularly in relation to sweet taste perception (Leszkowicz et al., 2024).

Improved performance under visual deprivation conditions has been previously demonstrated for other sensory modalities, particularly audition. A great deal of the evidence in this regard comes from studies with visually impaired participants, who may show exceptional performance in aspects such as auditory spatial processing (Collignon et al., 2009). Intriguingly, it has been shown that smaller (but noticeable) improvements may also be observed, even for short-term visual deprivation. For example, one study found that sighted individuals may experience improvements in the accuracy of sound localization after being blindfolded for a short period (90 min; Lewald, 2007). Pascual-Leone et al. (2005) have previously argued that such adaptations may reveal the potential of the brain, namely the occipital cortex, to process information related to other sensory modalities beyond vision. However, one question that has remained elusive so far is whether visual deprivation may not only enhance sensory processing in other modalities (namely, audition) but also increase its putative effects on a third sensory modality. For example, could visual deprivation lead to a more robust influence of sound on taste/flavor perception?

1.2. Sonic seasoning in a multimodal context

One significant adaptive advantage of multimodal perception is the ability to combine information from different sources (modalities) to enhance perceptual clarity and allow for a more effective mapping of the surrounding environment (Ernst & Bülthoff, 2004). The localization of objects in space is one example where one can combine, for example, visual (e.g., seeing a car approaching) and auditory (e.g., hearing the noise of the engine become more intense as the car gets closer) cues. Although one could deduct the proximity of the car from either of the two sensory modalities alone, it is easier to do so when the information from the two senses correlates. Some lab experiments also show improved stimulus processing in the presence of accessory crossmodal stimuli. For example, it has been reported that participants' visual sensitivity (i.e., the ability to detect a visual stimulus presented briefly amidst visual noise) may be improved by simultaneously presenting a pure sound (Haas et al., 2013). Specifically, sounds of a specific duration (between ~60 and ~96 ms) improved detection performance compared to sounds matching the visual stimulus' presentation time (~24 ms).

In the sonic seasoning literature, the question of crossmodal improvements has been scarcely explored. Recently, Guedes, Prada, Garrido, Caeiro, et al. (2023) found that listening to "sweet" (vs. less "sweet") music did not significantly improve sweet taste sensitivity. However, the authors reported that music could aid in increasing detection rates in near-threshold samples, where the stimulus' identity is more ambiguous. Indeed, previous studies suggested that sweet taste recognition in near-threshold samples may be increased by presenting congruent visual stimuli, such as round (vs. angular) shapes (Liang et al., 2013; Liang et al., 2016). Similar to the audio-gustatory experiment conducted by Guedes, Prada, Garrido, Caeiro, et al. (2023), one important aspect to consider here is the underlying crossmodal correspondences between visual shapes and tastes, namely the well-documented association between roundness and sweetness (Deroy & Valentin, 2011; Motoki et al., 2019; Ngo et al., 2013). This evidence suggests that crossmodal information may enhance perception in ambiguous situations where taste identity is uncertain but not absent. Under such circumstances, one could anticipate enhanced sonic seasoning effects.

If diminished information about gustatory stimuli can indeed increase reliance on other sensory modalities, such as audition, it is relevant to ask whether one should expect more robust effects of audition in taste perception in contexts of diminished sensory information. To our best knowledge, that has not been attempted so far in the context of taste intensity. Therefore, this study aims to investigate how sonic seasoning operates, specifically, when the visual identification of gustatory stimuli is diminished.

1.3. Aims and hypotheses

Considering the relevance of visual cues (namely, color) for the identification of tastes and flavors in foods and drinks, we examined the influence of high (vs. low) sweetness music on the perception of the taste of drinks presented in an unmasked (i.e., visible color) versus a masked condition (i.e., drinks presented in closed cups with opaque lid). Specifically, we expected that:

H1) The drinks would be evaluated in accordance with the crossmodal attributes of the music, such that the samples should be perceived as sweeter when tasted alongside sweet (vs. non-sweet) music.

H2) The effect of music would be more robust when visual cues were hidden from participants. Presenting the drinks in covered (vs. open) opaque cups should increase perceptual ambiguity, therefore increasing the prominence of auditory cues in the taste evaluation task. As such, we expect an interaction effect between music and visual masking conditions.

2. Materials and method

2.1. Participants and design

One hundred and thirty-two university students volunteered to participate in this experiment in exchange for course credit. Four participants reported anomalies with their survey (e.g., sound not playing correctly) and were excluded from the analyses. The final sample ($N = 128$; $M_{age} = 21.2$, $SD_{age} = 5$) included 115 participants who identified as women, 12 as men, and one as non-binary. Based on self-reported weight and height data, most participants (76.2 %) were classified as normoponderal (18.5 kg/m^2 < BMI < 25 kg/m^2), 9 % as underweight, and 14.8 % as overweight or obese. Participants did not receive training in sensory analysis prior to this study. The sample size was determined based on previous literature with comparable designs, mainly informed by the systematic review by Guedes, Garrido, Lamy, Cavalheiro, and Prada (2023).

Participants were randomly allocated to different experimental conditions where they tasted flavored aqueous samples presented in opaque white paper disposable cups (unmasked condition, $n = 65$) or in the same cups covered with a black opaque lid (masked condition, $n = 63$). In both cases, there were two sets of samples, each presented with a different musical background (sweet vs. non-sweet music) in randomized order. The two sets of samples were equivalent and included five aqueous solutions prepared with different flavored syrups. In summary, the study included one variable with two levels manipulated between participants (visual masking: unmasked vs. masked) and two variables manipulated within participants: one with two levels (music: sweet vs. non-sweet) and the other with five (sample type). See Fig. 1 for an overview of the experiment.

2.2. Materials

2.2.1. Gustatory stimuli

Given the study's objectives, the gustatory stimuli were chosen to represent a variety of flavors and colors. Accordingly, we included five distinct samples prepared by diluting flavored syrups (commercially available) in still mineral water (pH 6.24) at a 5.3 % concentration, which allowed for adequate color and flavor intensities. The flavored syrups' included mint (color: green), raspberry (color: maroon-red), coconut (color: white), "blue curaçao" (color: blue), and redcurrant (color: currant-red) with sugar contents ranging from 76.9 % to 81 %. All syrups were from the brand "Rioba," except for the redcurrant syrup, which was from the brand "Troféu." The samples were presented in white disposable paper cups (120 ml/4.1 oz). In the masked condition, these cups were covered with a black opaque plastic lid (with a small hole for drinking), which masked the sample's identity (see Supplementary Figure 1). Each sample was identified with a three-digit random code (unrelated to the samples).

2.2.2. Auditory stimuli

The soundtracks for this experiment were chosen to evoke varying degrees of associations with sweetness. To this end, we selected two excerpts from the Taste & Affect Music Database (Guedes, Prada, Garrido, & Lamy, 2023), a collection of royalty-free instrumental music covering different moods and genres. In the norming study, participants listened to several music excerpts, identified the taste category (sweet, bitter, sour, salty) that best matched each piece, and rated it across several emotions and affective dimensions (for the detailed procedures and stimuli, please, see Guedes, Prada, Garrido, & Lamy, 2023).

The two soundtracks used in the current study were selected based on the percentage of taste correspondences. For instance, the soundtrack selected as sweet (SW) ("Fruit of Lore" by Deskant) was associated with sweetness by 80.5 % of the norming sample (vs. 3.9 % associations with bitterness and 5.2 % with sourness). The non-sweet (NS) soundtrack ("Unearthly Desires" by Sage Oursler) had negligible associations with

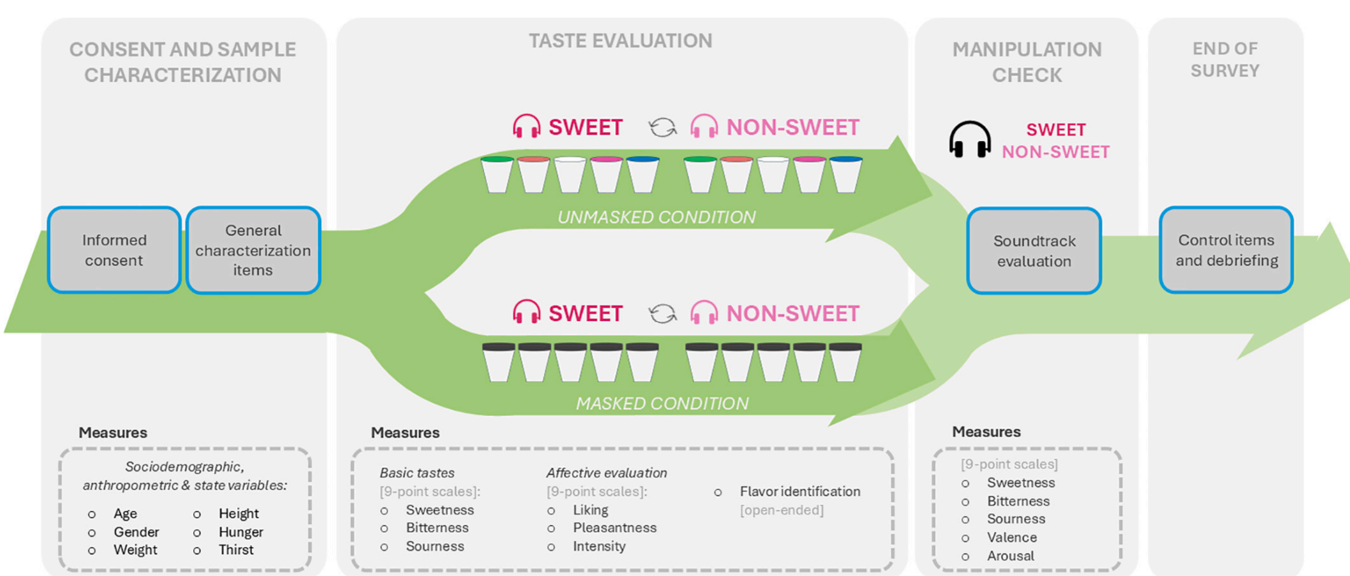

Fig. 1. Overview of the experiment.

the sweet taste in the norming sample (1.3 %). Instead, the soundtrack presented a mixed sour/bitter profile with 43.4 % associations with bitterness and 42.1 % with sourness. Both soundtracks consisted of 30-s excerpts played continuously during the tasting task.

2.3. Procedures

The experiment was approved by the ethics committee of Iscte - Instituto Universitário de Lisboa. Before signing up, participants were informed that the study procedures involved the consumption of drinks. The pre-study requirements included preserved sensory abilities at the time of the study (i.e., without impairments in gustatory, olfactory, and auditory function). Moreover, participants were instructed to refrain from eating, drinking coffee, brushing their teeth, or smoking the hour prior to participation. Before beginning the experiment, eligible participants were asked to report any food allergies/intolerances.

The study sessions were conducted at the university's Psychology Lab (LAPSO) in individual soundproof booths equipped with computers and headphones. All devices were kept at a comfortable sound volume level. Participants were told they would be asked to taste and evaluate different drinks following the instructions provided on the computer. All instructions and measures were integrated into a web survey programmed using Qualtrics software (Qualtrics, Provo, UT). The background music played automatically with sound controls concealed from respondents. The first section of the survey presented the informed consent form, and participants were asked to indicate their agreement/disagreement by ticking a box. After agreeing to participate, participants completed a short questionnaire containing basic sociodemographic (age, gender) and anthropometric variables (self-reported weight, height) before proceeding to the sample evaluation task. The final section of the survey included a set of control items (e.g., "Did you find any issues with the sound of this survey?") and a manipulation check where participants were asked to evaluate the two soundtracks reproduced in the main task. The survey concluded with a debriefing and contact information.

Lab sessions simultaneously accommodated up to 5 participants, each completing the experiment in individual booths. Each session was randomly assigned to one of the two (unmasked or masked) conditions. The order of presentation of music and drink samples (within participants) was fully counterbalanced. To minimize carryover effects, participants were asked to drink water and wait 30 s before proceeding to the next sample. For this purpose, a visual timer was presented in the survey, and participants were only allowed to proceed after this time had elapsed.

2.4. Measures

The drink samples were evaluated using 9-point rating scales anchored by bipolar labels ("Please, carefully taste sample [sample code] and rate it, using the provided scales"). The rating dimensions included three basic taste sensations, namely sweetness (1 = *Lowly sweet* to 9 = *Highly sweet*), bitterness (1 = *Lowly bitter* to 9 = *Highly bitter*), and sourness (1 = *Lowly sour* to 9 = *Highly sour*). Additionally, participants reported how much they liked the sample (1 = *I don't like it very much* to 9 = *I like it very much*) and evaluated the affective dimensions of pleasantness (1 = *Lowly pleasant* to 9 = *Highly pleasant*) and intensity (1 = *Lowly intense* to 9 = *Highly intense*). After rating each sample, participants were asked to identify the flavor of the drink in an open-ended item.

In the manipulation check, participants rated the soundtracks in sweetness, bitterness, sourness, pleasantness, and intensity using the same scales described above.

2.5. Data analytic plan

All hypotheses and the analytic plan were specified before data collection. Data analysis was conducted using IBM SPSS Statistics 29. First, soundtracks were compared based on the manipulation check ratings. Paired samples *t*-tests were computed for the taste (sweetness, sourness, bitterness) and emotional associations (valence arousal). Second, the effects of music condition and visual masking on sample evaluation were analyzed in a mixed ANOVA. The main dependent variable was the perceived sweetness of the drinks. However, considering that the music samples also differed in other taste associations (bitterness, sourness) and affective dimensions (valence, arousal), we repeated the same analysis for other variables of sample evaluation. Specifically, we explored the influence of music and visual masking on the remaining two taste variables (bitterness, sourness), as well as in the hedonic and affective evaluation of samples (liking, pleasantness, intensity). In all analyses, the independent variable "music condition" (within-participants) included the two soundtracks (sweet vs. non-sweet), whereas "visual masking" (between-participants) included the unmasked (vs. masked) presentation of the samples. Interactions were analyzed and reported when significant ($p < .050$). Pairwise comparisons were Bonferroni corrected.

Additionally, to analyze how visual and auditory conditions influenced the accuracy of flavor identification, we first scored participants' guesses as correct (score = 1) or incorrect (score = 0). Only fully precise answers were given a correct score (e.g., "raspberry" instead of "berries") considering the samples' dominant flavor, namely mint, raspberry, orange (blue curaçao), redcurrant, and coconut. The differences between unmasked and masked conditions (between participants) were evaluated using Chi-Square tests. When the observed frequency in one or more cells was lower than 5, we interpreted the result of Fisher's Exact test instead. Comparisons in flavor identification accuracy between the SW and NS music conditions (repeated measures) were computed using McNemar's test.

3. Results

3.1. Soundtrack comparison

Table 1 presents the soundtrack ratings obtained in the manipulation check. The results confirm that the two soundtracks differed significantly in sweetness associations (all $p < .001$). The SW soundtrack was evaluated as significantly sweeter than the NS soundtrack. The SW soundtrack was also perceived as significantly less bitter and less sour, as well as more pleasant and less intense.

3.2. Modulating taste perception through music in masked (vs. unmasked) conditions

The full data on basic tastes are presented in Table 2. The results of the mixed ANOVA showed that music significantly influenced the perceived sweetness of the drinks. As hypothesized, the drinks were rated as sweeter when participants listened to the SW (vs. NS) soundtrack. In the visual modality, no differences were found between the masked and unmasked conditions. A significant main effect of sample type suggested that participants ascribed different sweetness intensities according to the type of drink. Specifically, the coconut sample was evaluated as sweeter than the mint, raspberry, and redcurrant samples (all $p < .001$). The orange sample was evaluated as significantly less sweet than coconut ($p < .011$) but sweeter than mint, raspberry, and redcurrant (all $p < .002$).

The perceived bitterness of the samples was not significantly influenced by music or visual masking. Instead, the main differences in bitterness ratings were driven by the type of drink. Pairwise comparisons showed that the raspberry was the most bitter drink (all $p < .001$), followed by mint (all $p < .16$). No significant difference between the two (raspberry and mint) was found.

For sourness ratings, a significant main effect of music was observed. Specifically, participants provided higher sourness ratings in the NS than

Table 1
Soundtrack Evaluation (Means and Standard deviation) and Mean Difference Results (Paired Samples t-tests).

	Sweet music		Non-Sweet music					
	M	*SD*	*M*	*SD*	Dif.	*t*(127)	Sig. (two-tailed)	Cohen's *d*
Sweetness	7.32	1.5	2.46	1.42	4.86	24.24	<0.001	2.14
Bitterness	1.64	1.14	5.73	2.22	−4.09	19.00	<0.001	1.68
Sourness	1.62	1.2	4.94	2.38	−3.32	14.26	<0.001	1.26
Valence	7.72	1.3	3.15	1.6	4.57	21.97	<0.001	1.94
Intensity	4.51	2.36	7.55	1.71	−3.05	10.89	<0.001	0.96

Note. Dif. = Difference between mean values.

Table 2
Main effects of soundtrack, visual masking, and sample on basic taste variables.

	Sweet music		Non-sweet music				
(A) Soundtrack condition	*M*	*SE*	*M*	*SE*	*F* (1,126)	Sig. (two-tailed)	η_p^2
Sweetness	5.51	0.13	5.27	0.13	6.95	0.009	0.05
Bitterness	2.37	0.12	2.49	0.12	1.73	0.191	0.01
Sourness	2.08	0.10	2.26	0.11	4.64	0.033	0.04
	Unmasked		Masked				
(B) Visual masking	*M*	*SE*	*M*	*SE*	*F* (1,126)	Sig. (two-tailed)	η_p^2
Sweetness	5.50	0.17	5.29	0.17	0.79	0.375	0.01
Bitterness	2.57	0.15	2.29	0.16	1.65	0.201	0.01
Sourness	2.21	0.13	2.12	0.13	0.25	0.617	0.00
(C) Sample					*F* (4,504)	Sig. (two-tailed)	η_p^2
Sweetness					30.29	<0.001	0.19
Bitterness					12.78	<0.001	0.09
Sourness					26.16	<0.001	0.17

in the SW music condition. Again, there was no significant main effect of visual masking, but a significant main effect of the type of drink was observed. Notably, the orange, redcurrant, and coconut samples were evaluated as less sour than raspberry (all $p < .001$) and mint (all $p < .004$). The orange sample was evaluated as significantly sourer than the redcurrant and coconut samples (all $p < .008$).

3.3. Changes in hedonic and affective evaluation

The full results of the analysis of variance of the hedonic and affective variables are presented in Table 3. The results show a significant main effect of soundtrack on liking, with participants reporting greater enjoyment of the drinks when accompanied by the SW (vs. NS) music.

Table 3
Main effects of soundtrack, visual masking, and sample on hedonic and affective variables.

	Sweet music		Non-sweet music				
(A) Soundtrack condition	*M*	*SE*	*M*	*SD*	*F* (1,126)	Sig. (two-tailed)	η_p^2
Liking	4.31	0.14	4.13	0.14	5.23	0.024	0.04
Pleasantness	4.86	0.13	4.63	0.13	7.33	0.008	0.06
Intensity	5.03	0.13	5.15	0.13	1.65	0.201	0.01
	Unmasked		Masked				
(B) Visual masking	*M*	*SE*	*M*	*SD*	*F* (1,126)	Sig. (two-tailed)	η_p^2
Liking	4.49	0.18	3.94	0.19	4.34	0.039	0.03
Pleasantness	5.07	0.18	4.41	0.18	6.96	0.009	0.05
Intensity	5.31	0.17	4.88	0.17	3.11	0.080	0.02
(C) Sample					*F* (4,504)	Sig. (two-tailed)	η_p^2
Liking					0.31	0.869	0.00
Pleasantness					0.62	0.651	0.01
Intensity					50.14	<0.001	0.29

Moreover, participants liked the samples significantly more in the unmasked (vs. masked) condition.

In line with these results, participants also evaluated the samples as more pleasant with the SW (vs. NS) music. Again, participants found the samples significantly more pleasant in the unmasked (vs. masked) condition. A significant interaction between music and visual masking was observed, $F(1,126) = 9.75$, $p = .002$, $\eta_p^2 = 0.07$. Notably, pleasantness ratings were higher when participants listened to the SW ($M = 5.32$, $SE = 0.19$) than the NS soundtrack ($M = 4.83$, $SE = 0.18$) when the drinks were presented unmasked. In the masked condition, however, the ratings under the SW ($M = 4.4$, $SE = 0.18$) and the NS conditions ($M = 4.43$, $SE = 0.19$) remained similar.

No significant main effects of either (visual or auditory) manipulations were observed in the intensity ratings. Although not significantly different, intensity ratings tended to be higher when presented without a lid (unmasked condition) compared to when the samples were covered. There were significant differences between the samples, as suggested by the main effect of the drink type. Pairwise comparisons showed that participants evaluated the mint (all $p < .001$) and coconut samples (all $p < .009$) as more intense than the raspberry, orange, and redcurrant samples. The redcurrant drink was significantly less intense than the raspberry and orange samples ($p < .001$).

3.4. Accuracy in flavor identification

Results of the Chi-Square tests did not indicate significant differences in participants' flavor identification when comparing the two (masked vs. unmasked) visual masking conditions (all $p > .119$). The full data are presented in the Supplementary Table 1. The results of McNemar's test suggest that accuracy in flavor identification also did not vary according to the music condition (all $p > .344$). The full data are presented in the Supplementary Table 2.

4. Discussion

There is consistent evidence that music can exert a significant influence on the sensory evaluation of foods and drinks, particularly for the sweet taste (Guedes, Garrido, Lamy, Cavalheiro, & Prada, 2023). In this study, we explored this "sonic sweetening" effect under two different conditions, where the color of different flavored drinks was either visible or hidden from participants (i.e., served in open vs. closed cups with an opaque lid). In line with prior research, this study found that when participants listened to a soundtrack more associated with the sweet taste, they rated the drinks as sweeter (Guedes et al., 2024). However, contrary to our hypotheses, this effect was not enhanced in the absence of color cues (i.e., no significant interaction was observed).

4.1. Is it the drink or is it the music?

Crossmodal correspondences between sounds and taste have been extensively reported in the literature (for reviews, see Guedes, Garrido, Lamy, Cavalheiro, & Prada, 2023; Rodríguez et al., 2023). The possibility of evoking tasting associations based on pairs of contrasting soundtracks was again shown in the current study. The rating data obtained in the manipulation check corroborate the findings of the norming study, where both music pieces were originally tested (Guedes, Prada, Garrido, & Lamy, 2023). Crucially, the two soundtracks differed significantly in the degree of association with the sweet taste, and this difference was the largest among all measures. The evaluation of other taste dimensions (bitterness and sourness) and affective variables also differed significantly and in line with the findings of the norming study. While this may not seem a surprising finding in itself, it is noteworthy that music-taste associations still emerged when assessed with quantitative scales (rather than in a forced-choice task akin to the original norming study). Although prevalently used in the field, forced-choice items may draw criticism due to the potential risk of inflating sample consensus. Moreover, it has also been questioned whether this type of choice architecture facilitates a sort of "demand effect" that may not accurately reflect genuine and spontaneous crossmodal associations (Knöferle et al., 2015; Wan et al., 2014).

A second key finding of the current study was that crossmodal attributes that distinguished between the two soundtracks had visible consequences on sample evaluation. As expected, the most notorious change was observed in sweetness ratings. The soundtrack more associated with the sweet taste contributed to enhancing the perceived intensity of this gustatory sensation across the samples. As suggested in previous literature, sweet music can be described in terms of a combination of specific psychoacoustic features (e.g., consonant harmony, legato articulation) and an emotional tone that is generally at the intersection of calm and pleasantness (Guedes, Prada, Garrido, & Lamy, 2023; Mesz et al., 2011; Rodríguez et al., 2023; Wang et al., 2015). This leaning toward positive affect may help explain why the current study has also found an improvement in hedonic measures in the sweet music condition, in line with previous research (Guedes et al., 2024; Guedes, Prada, Lamy, & Garrido, 2023). According to the 'sensation transfer' hypothesis, the positive feelings toward music may carry over to the evaluation of foods and beverages (Cheskin, 1972; Reinoso-Carvalho et al., 2016). This hypothesis entails not only that music evoking more positive affect can improve the hedonic evaluation of the food or drink itself, but also enhance the salience of sensory attributes that are also pleasant, such as sweetness (Kantono et al., 2016; Kantono et al., 2019).

An intriguing observation was that while sweet (vs. non-sweet) music significantly decreased sourness ratings, the same did not occur for bitterness (at least, not to a significant extent). Although there may not be a straightforward explanation for this, it is possible that simultaneously assessing different basic tastes may pose challenges for some participants. This limitation may be particularly relevant to our study, as it was conducted with lay participants who, without formal training in sensory evaluation, are more prone to misconceptions, such as confusing bitterness with sourness (Doty et al., 2017; O'Mahony et al., 1979). One way to address this in future studies could involve offering prior training in sensory evaluation or providing concrete examples for basic taste sensations (e.g., lemon for sour, coffee for bitter).

4.2. *Visual masking and its role in 'sonic sweetening'*

The central question this study aimed to answer was how the availability of visual information may modulate a sonic sweetening effect. For this purpose, one key visual cue (i.e., color) was concealed from participants by using opaque lids. Overall, the absence of a significant (sound*masking) interaction suggested that this masking approach did not enhance the effectiveness of the auditory manipulation in shaping the evaluation of taste-related attributes. Moreover, there was no indication of a main effect of visual masking (unmasked vs. masked) on any of the taste ratings. There was, however, one exception respecting the hedonic and affective variables. When participants were unable to see what the samples looked like, they provided lower liking and valence ratings. Thus, it seems that although covering the drinks did not significantly change perception at the gustatory level, it worsened participants' overall hedonic experience.

As the popular adage goes, "we eat with our eyes first" (Delwiche, 2012). The sight of foods is one key element of the cephalic phase when the organism organizes a set of bodily responses in advance of ingestion (Smeets et al., 2010). Viewing appetizing foods may even trigger a desire to eat in the absence of hunger (Passamonti et al., 2009), and the visual appearance of foods and drinks is one determinant aspect of their acceptance (Wadhera & Capaldi-Phillips, 2014). It is thus to be expected that the hedonic experience may deteriorate when these cues are less readily accessible. For example, in one experiment, participants tasted ice cream samples with or without blindfolds. Although the use of blindfolds did not substantially change the taste evaluation (in this case, sweetness), participants without blindfolds provided higher pleasantness ratings and reported higher willingness to buy the products (Renner et al., 2016). Besides the seemingly obvious conclusion that people like to see what they eat, we should also consider how visual masking techniques may contribute to a less familiar – possibly less comfortable – consumption experience. Most people are simply not accustomed to eating with blindfolds and, perhaps more relevant to the current study, disposable cups with opaque lids are common for hot beverages like coffee or tea but are much less typical for soft drinks.

One of the questions that motivated this work was understanding whether the effect of music on taste perception could be enhanced in a visual masking condition, given the reduced availability of visual cues. The findings obtained in this study did not support this hypothesis, as there was no evidence of a significant interaction between music and visual masking conditions for any of the taste dimensions. The data regarding flavor identification may provide additional insights to understand this pattern of results. According to the obtained data, visual masking did not decrease participants' ability to recognize the dominant flavor of the samples (e.g., mint). Therefore, it seems that participants in the two groups were roughly equally likely to correctly guess the flavor of the drink. If flavor is indeed a pivotal sensory cue for taste judgments, for example, based on previous knowledge and natural correlations (e.g., knowing that orange flavor and sour taste often co-occur; Lim et al., 2014; Stevenson et al., 1995), visual masking may have been simply not enough to create the type of perceptual ambiguity that would be needed to motivate a higher reliance on extrinsic auditory cues (Guedes, Prada, Garrido, Caeiro, et al., 2023). To further test this hypothesis, it could be worthwhile replicating this study with participants fully deprived of visual input (e.g., blindfolded), a situation that could possibly inspire higher reliance on the remaining senses. Another possibility could be to explore whether less recognizable taste-flavor intensities (e.g., near recognition thresholds) could also heighten the reliance on auditory cues (for instance, see Guedes, Prada, Garrido, Caeiro, et al., 2023). As the main effect of sample type suggests, differences in basic taste ratings were still highly dependent on the sensory attributes (e.g., flavor) of the drinks under study.

Although visual masking did not change the strength or direction of the effect of music in taste evaluation, pleasantness ratings tell a different story. Notably, a significant interaction showed that sweet music led to higher pleasantness ratings in the unmasked condition, whereas in the masked condition, the perceived pleasantness remained nearly unchanged (and below the mean ratings provided in the unmasked condition). While this interaction was not significant in the case of liking ratings, it is nevertheless important to reflect on the possible implications of this finding to the affective responses to food and their putative implications for acceptance. For example, future studies in the field may need to consider that the way in which samples are presented may compromise any expected effects of music on affective reactions. Similarly, in an applied setting, concealing visual cues (such as when serving a drink in a closed cup) could inadvertently buffer the positive impact one could expect from the musical ambiance. Understanding these dynamics may be key in designing more congruent and intelligent servicescapes.

4.3. Limitations

Until now, we have been referring to the use of opaque lids in this study as a purely visual manipulation. However, the fact that these lids possess only a small orifice for drinking also likely presents some limitations to the sense of olfaction. Odorants can reach the olfactory epithelium through two different routes. Broadly, orthonasal olfaction refers to the perception of volatile molecules that are inhaled through the nose, whereas the retronasal route involves the passage of these molecules from the oral cavity through the nasopharynx (Kringelbach et al., 2009). By restricting the available open surface of the cups, we may also be decreasing the number of volatiles that will reach the orthonasal route. Therefore, it could be said that this manipulation has at least one element of olfactory restriction in addition to the visual modality, as we have addressed thus far. It is possible that the use of opaque lids in the masked condition introduced other relevant variations, including the weight of the cups, a greater constriction in terms of fluid flow or even the trigeminal sensations originating from the different surfaces of contact. Possible consequences, such as overall intake or mouthfeel sensations, were unaccounted for in the present study. The absence of a significant main effect on most of the dependent variables suggests that the consequences of this manipulation may have been limited to specific aspects of the hedonic and affective experience. Still, future studies could explore alternative visual masking methods to enhance experimental control, particularly by standardizing attributes that may engage other senses, such as the weight or texture of the cups discussed above. One possibility could be, for instance, to use colorless flavorants and explore contrasts between colored and transparent solutions.

The current findings provide relevant insights regarding one particular form of visual masking, which might not be generalizable to other common techniques (such as blindfolding or ambient color manipulations; Sipos et al., 2021). For example, blindfolding allows for a virtually complete deprivation of sight, thus reducing the influence of other environmental cues apart from the target samples themselves. It is questionable whether merely dissimulating the samples' colors by covering their containers is sufficient to increase the reliance on auditory cues or whether a more drastic (and perhaps more long-lasting) form of visual deprivation should be in place (e.g., Lewald, 2007). Nevertheless, there is still interest in exploring the consequences of subtle manipulations one may find in our everyday lives (i.e., covered cups), as this search can often lead us to novel insights with potential practical applications.

Lastly, an additional limitation of this study could be the participant's lack of training in sensory evaluation. Although the experimental procedures were kept to a minimal complexity level, we are unable to estimate if participants' previous knowledge and familiarity with taste evaluation (e.g., knowledge regarding basic taste categories and their differentiation, Doty et al., 2017; O'Mahony et al., 1979) might have influenced their evaluative judgments.

5. Conclusions and implications

The current study explored the possibility of modulating the gustatory experience through music in a visual masking context. From a gustatory standpoint, the use of a simple masking strategy did not significantly affect the efficacy of the musical manipulation. This finding reinforces the relevance of auditory cues, whose effect was observed not only across visual conditions but also across the drink samples under analysis, that varied in multiple aspects like color and flavor. Although more research is still needed, namely with different foods/beverages, these findings seem to encourage the use of music as a taste enhancement strategy even in situations when products are visually concealed (e.g., coffee-to-go).

From an applied standpoint, it is worth highlighting the possibility that opaque lids can diminish enjoyment. However, these findings should be interpreted with caution, as it remains unclear whether this effect is specific to the drinks tested (where covered cups may be less common) or if it can be generalized to other types of drinks. A previous experiment found that plastic lids did not negatively impact the consumption of iced coffee beverages, and lids were even found preferable to alternative drinking methods (e.g., paper straw; Beekman et al., 2021). However, Beekman and colleagues used transparent rather than opaque lids, which could impact the sensory experience differently. Although the differential impact of the various packaging materials and/or drinking methods is beyond the scope of the current work, it certainly deserves further scientific exploration.

With the growing realization that contextual cues, such as packaging and tableware, have valuable implications for eating experiences and behaviors (Spence, 2016; Spence et al., 2012; Velasco & Spence, 2019), there is scientific and commercial interest in optimizing the use of these extrinsic cues. In this context, sound also plays a fundamental role. As a key and often distinguishing feature of eating environments, sound can make a difference between loving or hating a meal (e.g., noisy restaurants; Alamir & Hansen, 2021; Novak et al., 2010; Raab et al., 2013). Music, particularly, is an easily accessible and highly flexible resource for building pleasant and comfortable dining atmospheres (Chen & Kang, 2017; Mathiesen et al., 2022; North & Hargreaves, 1996). The evidence supporting its potential contribution to healthier eating is relatively recent (Biswas et al., 2019; Huang & Labroo, 2020). Nonetheless, there is emerging evidence that sonic seasoning may offer valuable insights, namely in what concerns improving the acceptance of healthier (e.g., lower sugar) alternatives (Guedes et al., 2024; Guedes, Prada, Lamy, & Garrido, 2023). Currently, we still need more research around this possibility, namely, with respect to the circumstances, individual determinants, and/or underlying mechanisms that may help unlock the full potential of audition for food perception. One possible pathway is that of studying the interactions between audition and the other sensory modalities (such as the visual domain pursued here). Real-world eating environments are made of multiple, mutually interacting sensory influences. Thus, understanding how to orchestrate the senses in a concerted manner might be crucial to improving not only the quality of the eating experience but potentially also its associated health outcomes.

Ethical Statement

The study was approved by the ethical review board of Iscte – Instituto Universitário de Lisboa (Approval #117/2020).

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CRediT authorship contribution statement

David Guedes: Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Marília Prada:** Writing – review & editing, Methodology, Conceptualization. **Margarida V. Garrido:** Writing – review & editing, Methodology, Conceptualization.

Declaration of competing interest

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

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2024.105418.

References

Alamir, M. A., & Hansen, K. (2021). The effect of type and level of background noise on food liking: A laboratory non-focused listening test. *Applied Acoustics, 172*, Article 107600. https://doi.org/10.1016/j.apacoust.2020.107600

Auvray, M., & Spence, C. (2008). The multisensory perception of flavor. *Consciousness and Cognition, 17*(3), 1016–1031. https://doi.org/10.1016/j.concog.2007.06.005

Beekman, T. L., Huck, L., Claure, B., & Seo, H.-S. (2021). Consumer acceptability and monetary value perception of iced coffee beverages vary with drinking conditions using different types of straws or lids. *Food Research International, 140*, Article 109849. https://doi.org/10.1016/j.foodres.2020.109849

Biswas, D., Lund, K., & Szocs, C. (2019). Sounds like a healthy retail atmospheric strategy: Effects of ambient music and background noise on food sales. *Journal of the Academy of Marketing Science, 47*(1), 37–55. https://doi.org/10.1007/s11747-018-0583-8

Bravo-Moncayo, L., Reinoso-Carvalho, F., & Velasco, C. (2020). The effects of noise control in coffee tasting experiences. *Food Quality and Preference, 86*, Article 104020. https://doi.org/10.1016/j.foodqual.2020.104020

Chen, X., & Kang, J. (2017). Acoustic comfort in large dining spaces. *Applied Acoustics, 115*, 166–172. https://doi.org/10.1016/j.apacoust.2016.08.030

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

Collignon, O., Voss, P., Lassonde, M., & Lepore, F. (2009). Cross-modal plasticity for the spatial processing of sounds in visually deprived subjects. *Experimental Brain Research, 192*(3), 343–358. https://doi.org/10.1007/s00221-008-1553-z

Crisinel, A.-S., & Spence, C. (2009). Implicit association between basic tastes and pitch. *Neuroscience Letters, 464*(1), 39–42. https://doi.org/10.1016/j.neulet.2009.08.016

Crisinel, A.-S., & Spence, C. (2010). A sweet sound? Food names reveal implicit associations between taste and pitch. *Perception, 39*(3), 417–425. https://doi.org/10.1068/p6574

Delwiche, J. F. (2012). You eat with your eyes first. *Physiology & Behavior, 107*(4), 502–504. https://doi.org/10.1016/j.physbeh.2012.07.007

Deroy, O., & Valentin, D. (2011). Tasting liquid shapes: Investigating the sensory basis of cross-modal correspondences. *Chemosensory Perception, 4*(3), 80–90. https://doi.org/10.1007/s12078-011-9097-1

Doty, R. L., Chen, J. H., & Overend, J. (2017). Taste quality confusions: Influences of age, smoking, PTC taster status, and other subject characteristics. *Perception, 46*(3–4), 257–267. https://doi.org/10.1177/0301006616685577

Dubose, C. N., Cardello, A. V., & Maller, O. (1980). Effects of colorants and flavorants on identification, perceived flavor intensity, and hedonic quality of fruit-flavored beverages and cake. *Journal of Food Science, 45*(5), 1393–1399. https://doi.org/10.1111/j.1365-2621.1980.tb06562.x

Ernst, M. O., & Bülthoff, H. H. (2004). Merging the senses into a robust percept. *Trends in Cognitive Sciences, 8*(4), 162–169. https://doi.org/10.1016/j.tics.2004.02.002

Fletcher, L., Heymann, H., & Ellersieck, M. (1991). Effects of visual masking techniques on the intensity rating of sweetness of gelatins and lemonades. *Journal of Sensory Studies, 6*(3), 179–191. https://doi.org/10.1111/j.1745-459X.1991.tb00513.x

Guedes, D., Garrido, M. V., Lamy, E., Cavalheiro, B. P., & Prada, M. (2023). Crossmodal interactions between audition and taste: A systematic review and narrative synthesis. *Food Quality and Preference, 107*, Article 104856. https://doi.org/10.1016/j.foodqual.2023.104856

Guedes, D., Garrido, M. V., Lamy, E., & Prada, M. (2024). Disentangling cross-modality and affect in "sonic seasoning": The effect of music associated with different degrees of sweetness and valence on food perception. *International Journal of Gastronomy and Food Science, 35*, Article 100879. https://doi.org/10.1016/j.ijgfs.2024.100879

Guedes, D., Prada, M., Garrido, M. V., Caeiro, I., Simões, C., & Lamy, E. (2023). Sensitive to music? Examining the crossmodal effect of audition on sweet taste sensitivity. *Food Research International, 173*, Article 113256. https://doi.org/10.1016/j.foodres.2023.113256

Guedes, D., Prada, M., Garrido, M. V., & Lamy, E. (2023). The taste & affect music database: Subjective rating norms for a new set of musical stimuli. *Behavior Research Methods, 55*(3), 1121–1140. https://doi.org/10.3758/s13428-022-01862-z

Guedes, D., Prada, M., Lamy, E., & Garrido, M. V. (2023). Sweet music influences sensory and hedonic perception of food products with varying sugar levels. *Food Quality and Preference, 104*, Article 104752. https://doi.org/10.1016/j.foodqual.2022.104752

Haas, B.d., Cecere, R., Cullen, H., Driver, J., & Romei, V. (2013). The duration of a co-occurring sound modulates visual detection performance in humans. *PLoS One, 8*(1), Article e54789. https://doi.org/10.1371/journal.pone.0054789

Huang, X.(I.), & Labroo, A. A. (2020). Cueing morality: The effect of high-pitched music on healthy choice. *Journal of Marketing, 84*(6), 130–143. https://doi.org/10.1177/0022242918813577

International Olive Council. (2020). *Standard COI/T.20/Doc. No 5/Rev. 2/2020. Sensory analysis of olive oil standard. Glass for oil tasting.* International Olive Council. https://www.internationaloliveoil.org/wp-content/uploads/2020/05/COI-T.20-Doc5-Rev2-2020-EN.pdf.

Johnson, J., & Clydesdale, F. M. (1982). Perceived sweetness and redness in colored sucrose solutions. *Journal of Food Science, 47*(3), 747–752. https://doi.org/10.1111/j.1365-2621.1982.tb12706.x

Kantono, K., Hamid, N., Shepherd, D., Lin, Y. H. T., Skiredj, S., & Carr, B. T. (2019). Emotional and electrophysiological measures correlate to flavour perception in the presence of music. *Physiology & Behavior, 199*, 154–164. https://doi.org/10.1016/j.physbeh.2018.11.012

Kantono, K., Hamid, N., Shepherd, D., Yoo, M. J. Y., Grazioli, G., & Carr, B. T. (2016). Listening to music can influence hedonic and sensory perceptions of gelati. *Appetite, 100*, 244–255. https://doi.org/10.1016/j.appet.2016.02.143

Knöferle, K., & Spence, C. (2012). Crossmodal correspondences between sounds and tastes. *Psychonomic Bulletin & Review, 19*(6), 992–1006. https://doi.org/10.3758/s13423-012-0321-z

Knöferle, K. M., Woods, A., Käppler, F., & Spence, C. (2015). That sounds sweet: Using cross-modal correspondences to communicate gustatory attributes. *Psychology & Marketing, 32*(1), 107–120. https://doi.org/10.1002/mar.20766

Kringelbach, M. L., Berridge, K. C., Kringelbach, M. L., & Berridge, K. C. (2009). *Pleasures of the brain*. Oxford University Press.

Leszkowicz, E., Pham, H. N., Nguyen, M. T. T., Vu, H. S., Ky, S. C., & Świergiel, A. H. (2024). Deprivation of visual stimuli increases sensitivity to sweet taste in a Vietnamese Kinh population. *Food Quality and Preference, 115*, Article 105129. https://doi.org/10.1016/j.foodqual.2024.105129

Leszkowicz, E., Szymanek, P., Pych, E., Danielczuk, J., Skąpska, S., & Świergiel, A. H. (2023). The effect of visual deprivation on basic taste modalities. *Journal of Sensory Studies, 38*(6), Article e12869. https://doi.org/10.1111/joss.12869

Lewald, J. (2007). More accurate sound localization induced by short-term light deprivation. *Neuropsychologia, 45*(6), 1215–1222. https://doi.org/10.1016/j.neuropsychologia.2006.10.006

Liang, P., Biswas, P., Vinnakota, S., Fu, L., Chen, M., Quan, Y., Zhan, Y., Zhang, G., & Roy, S. (2016). Invariant effect of vision on taste across two Asian cultures: India and China. *Journal of Sensory Studies, 31*(5), 416–422. https://doi.org/10.1111/joss.12225

Liang, P., Roy, S., Chen, M.-L., & Zhang, G.-H. (2013). Visual influence of shapes and semantic familiarity on human sweet sensitivity. *Behavioural Brain Research, 253*, 42–47. https://doi.org/10.1016/j.bbr.2013.07.001

Lim, J., Fujimaru, T., & Linscott, T. D. (2014). The role of congruency in taste–odor interactions. *Food Quality and Preference, 34*, 5–13. https://doi.org/10.1016/j.foodqual.2013.12.002

Maga, J. A. (1974). Influence of color on taste thresholds. *Chemical Senses, 1*(1), 115–119. https://doi.org/10.1093/chemse/1.1.115

Mathiesen, S. L., Hopia, A., Ojansivu, P., Byrne, D. V., & Wang, Q. J. (2022). The sound of silence: Presence and absence of sound affects meal duration and hedonic eating experience. *Appetite, 174*, Article 106011. https://doi.org/10.1016/j.appet.2022.106011

Mesz, B., Trevisan, M. A., & Sigman, M. (2011). The taste of music. *Perception, 40*(2), 209–219. https://doi.org/10.1068/p6801

Morrot, G., Brochet, F., & Dubourdieu, D. (2001). The color of odors. *Brain and Language, 79*(2), 309–320. https://doi.org/10.1006/brln.2001.2493

Motoki, K., Saito, T., Nouchi, R., Kawashima, R., & Sugiura, M. (2019). Round faces are associated with sweet foods: The role of crossmodal correspondence in social perception. *Foods, 8*(3), Article 3. https://doi.org/10.3390/foods8030103

Ngo, M. K., Velasco, C., Salgado, A., Boehm, E., O'Neill, D., & Spence, C. (2013). Assessing crossmodal correspondences in exotic fruit juices: The case of shape and sound symbolism. *Food Quality and Preference, 28*(1), 361–369. https://doi.org/10.1016/j.foodqual.2012.10.004

North, A. C., & Hargreaves, D. J. (1996). The effects of music on responses to a dining area. *Journal of Environmental Psychology, 16*(1), 55–64. https://doi.org/10.1006/jevp.1996.0005

Novak, C. C., La Lopa, J., & Novak, R. E. (2010). Effects of sound pressure levels and sensitivity to noise on mood and behavioral intent in a controlled fine dining restaurant environment. *Journal of Culinary Science & Technology, 8*(4), 191–218. https://doi.org/10.1080/15428052.2010.535756

O'Mahony, M., Goldenberg, M., Stedmon, J., & Alford, J. (1979). Confusion in the use of the taste adjectives 'sour' and 'bitter'. *Chemical Senses, 4*(4), 301–318. https://doi.org/10.1093/chemse/4.4.301

Parr, W. V., Geoffrey White, K., & Heatherbell, D. A. (2003). The nose knows: Influence of colour on perception of wine aroma. *Journal of Wine Research, 14*(2–3), 79–101. https://doi.org/10.1080/09571260410001677969

Pascual-Leone, A., Amedi, A., Fregni, F., & Merabet, L. B. (2005). The plastic human brain cortex. *Annual Review of Neuroscience, 28*(1), 377–401. https://doi.org/10.1146/annurev.neuro.27.070203.144216

Passamonti, L., Rowe, J. B., Schwarzbauer, C., Ewbank, M. P., Von Dem Hagen, E., & Calder, A. J. (2009). Personality predicts the brain's response to viewing appetizing foods: The neural basis of a risk factor for overeating. *The Journal of Neuroscience, 29*(1), 43–51. https://doi.org/10.1523/JNEUROSCI.4966-08.2009

Piqueras-Fiszman, B., Alcaide, J., Roura, E., & Spence, C. (2012). Is it the plate or is it the food? Assessing the influence of the color (black or white) and shape of the plate on the perception of the food placed on it. *Food Quality and Preference, 24*(1), 205–208. https://doi.org/10.1016/j.foodqual.2011.08.011

Raab, C., Zemke, D. M. V., Hertzman, J. L., & Singh, D. (2013). Restaurant customers' perceptions of noise and their satisfaction and loyalty behaviors. *International Journal of Hospitality & Tourism Administration, 14*(4), 398–414. https://doi.org/10.1080/15256480.2013.838090

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. https://doi.org/10.1016/j.foodqual.2016.03.009

Renner, B., Sproesser, G., Stok, F. M., & Schupp, H. (2016). Eating in the dark: A dissociation between perceived and actual food consumption. *Food Quality and Preference, 50*, 145–151. https://doi.org/10.1016/j.foodqual.2016.02.010

Rodríguez, B., Reyes, L. H., & Reinoso-Carvalho, F. (2023). Exploring crossmodal associations between sound and the chemical senses: A systematic review including interactive visualizations. *Multisensory Research, 36*(8), 725–825. https://doi.org/10.1163/22134808-bja10107

Ross, C. F., Bohlscheid, J., & Weller, K. (2008). Influence of visual masking technique on the assessment of 2 red wines by trained and consumer assessors. *Journal of Food Science, 73*(6), S279–S285. https://doi.org/10.1111/j.1750-3841.2008.00824.x

Roth, H. A., Radle, L. J., Gifford, R., & Clydesdale, F. M. (1988). Psychophysical relationships between perceived sweetness and color in lemon- and lime-flavored drinks. *Journal of Food Science, 53*(4), 1116–1119. https://doi.org/10.1111/j.1365-2621.1988.tb13543.x

Sipos, L., Nyitrai, Á., Szabó, D., Urbin, Á., & Nagy, B. V. (2021). Former and potential developments in sensory color masking – Review. *Trends in Food Science & Technology, 111*, 1–11. https://doi.org/10.1016/j.tifs.2021.02.050

Skrzypulec, B. (2021). Constitutivity in flavour perception. *Erkenntnis*. https://doi.org/10.1007/s10670-021-00503-9

Small, D. M. (2012). Flavor is in the brain. *Physiology & Behavior, 107*(4), 540–552. https://doi.org/10.1016/j.physbeh.2012.04.011

Smeets, P. A., Erkner, A., & De Graaf, C. (2010). Cephalic phase responses and appetite. *Nutrition Reviews, 68*(11), 643–655. https://doi.org/10.1111/j.1753-4887.2010.00334.x

Spence, C. (2015). Multisensory flavor perception. *Cell, 161*(1), 24–35. https://doi.org/10.1016/j.cell.2015.03.007

Spence, C. (2016). Multisensory packaging design: Color, shape, texture, sound, and smell. In P. Burgess (Ed.), *Integrating the packaging and product experience in food and beverages* (pp. 1–22). Woodhead Publishing. https://doi.org/10.1016/B978-0-08-100356-5.00001-2.

Spence, C. (2023). Digitally enhancing tasting experiences. *International Journal of Gastronomy and Food Science, 32*, Article 100695. https://doi.org/10.1016/j.ijgfs.2023.100695

Spence, C., Harrar, V., & Piqueras-Fiszman, B. (2012). Assessing the impact of the tableware and other contextual variables on multisensory flavour perception. *Flavour, 1*(1), 7. https://doi.org/10.1186/2044-7248-1-7

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

Spence, C., Reinoso-Carvalho, F., Velasco, C., & Wang, Q. J. (2019). Extrinsic auditory contributions to food perception & consumer behaviour: An interdisciplinary review. *Multisensory Research, 32*(4–5), 275–318. https://doi.org/10.1163/22134808-20191403

Stevenson, R. J., Prescott, J., & Boakes, R. A. (1995). The acquisition of taste properties by odors. *Learning and Motivation, 26*(4), 433–455. https://doi.org/10.1016/S0023-9690(05)80006-2

Velasco, C., & Spence, C. (Eds.). (2019). *Multisensory packaging: Designing new product experiences*. Springer International Publishing. https://doi.org/10.1007/978-3-319-94977-2.

Wadhera, D., & Capaldi-Phillips, E. D. (2014). A review of visual cues associated with food on food acceptance and consumption. *Eating Behaviors, 15*(1), 132–143. https://doi.org/10.1016/j.eatbeh.2013.11.003

Wan, X., Woods, A. T., van den Bosch, J. J. F., McKenzie, K. J., Velasco, C., & Spence, C. (2014). Cross-cultural differences in crossmodal correspondences between basic tastes and visual features. *Frontiers in Psychology, 5*. https://doi.org/10.3389/fpsyg.2014.01365

Wang, Q. J., Keller, S., & Spence, C. (2017). Sounds spicy: Enhancing the evaluation of piquancy by means of a customised crossmodally congruent soundtrack. *Food Quality and Preference, 58*, 1–9. https://doi.org/10.1016/j.foodqual.2016.12.014

Wang, Q. J., & Spence, C. (2019). Drinking through rosé-coloured glasses: Influence of wine colour on the perception of aroma and flavour in wine experts and novices. *Food Research International, 126*, Article 108678. https://doi.org/10.1016/j.foodres.2019.108678

Wang, Q. J., Woods, A. T., & Spence, C. (2015). "What's your taste in music?" A comparison of the effectiveness of various soundscapes in evoking specific tastes. *I-Perception, 6*(6), Article 204166951562200. https://doi.org/10.1177/2041669515622001

Woods, A. T., Poliakoff, E., Lloyd, D. M., Kuenzel, J., Hodson, R., Gonda, H., … Thomas, A. (2011). Effect of background noise on food perception. *Food Quality and Preference, 22*(1), 42–47. https://doi.org/10.1016/j.foodqual.2010.07.003

Zampini, M., Sanabria, D., Phillips, N., & Spence, C. (2007). The multisensory perception of flavor: Assessing the influence of color cues on flavor discrimination responses. *Food Quality and Preference, 18*(7), 975–984. https://doi.org/10.1016/j.foodqual.2007.04.001

Zampini, M., Wantling, E., Phillips, N., & Spence, C. (2008). Multisensory flavor perception: Assessing the influence of fruit acids and color cues on the perception of fruit-flavored beverages. *Food Quality and Preference, 19*(3), 335–343. https://doi.org/10.1016/j.foodqual.2007.11.001