Sweet music influences sensory and hedonic perception of food products with varying sugar levels

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Abstract

Reducing sugar intake is an important nutritional goal in most developed countries. Despite the health consequences of excessive sugar consumption (e.g., non-communicable diseases), individuals are often reluctant to shift dietary habits due to the high hedonic appeal of sugar-rich products. Manipulating the intrinsic sensory attributes of foods (such as color or aroma) has been put forward as a promising framework for enhancing taste perception and increasing acceptance of low-sugar products. So far, it is less known whether extrinsic sensory cues may have similar effects.

In this within-subjects experiment (*N* = 106, 64% women), we tested how auditory stimuli (i.e., music) may impact the perception and acceptance of products varying in sweetness levels. Participants tasted samples of two product categories (vegetables and cookies), with higher (carrots and cookies) and lower sweetness levels (cucumbers and 0% sugar cookies), while listening to previously tested soundtracks that were strongly (vs. weakly) associated with sweetness.

Results showed that the high "sweetness" soundtrack increased the sweetness ratings of all products compared to the low "sweetness" soundtrack. Participants also reported higher preference and more favorable intentions of future consumption when the high "sweetness" soundtrack was played. Overall, these findings suggest that extrinsic sensory cues, namely music, may aid in reducing sugar intake by increasing the acceptance of products with lower sugar content.

Keywords: crossmodal perception, sweet taste, healthy eating, sugar intake, music

1. Introduction

Sweets are among the most desired and palatable foods. Products like cookies, ice creams, or chocolates are commonly referred to as comfort foods due to their ability to trigger pleasant psychological states (Wansink & Sangerman, 2000). Human preference for sweet seems to result from a "perfect storm" of biological and psychological determinants. On the one hand, there are innate predispositions for seeking sweet- and avoiding bitter-tasting foods since early in ontogeny. On the other hand, in most Western countries, there is constant exposure to abundant, often highly processed, sweet foods, commonly associated with feelings of pleasure and reward (Mennella & Bobowski, 2015). Unsurprisingly, overconsumption of sugar is pervasive in most developed countries and is expected to continue rising, according to projections of OECD and FAO (2020). The worrisome implications of this nutritional imbalance include increased risks for obesity and non-communicable diseases, such as diabetes or cardiovascular and respiratory diseases (World Health Organization, 2015).

While several countries are implementing measures to reduce sugar intake, this may be a challenging endeavor due to the negative consequences of sugar reduction for eating enjoyment. For manufacturers, developing new sugar-reduced versions of food products often comes at the cost of sacrificing sensory appeal (e.g., taste, texture) and consumer acceptance (de Souza et al., 2021; Prada et al., 2022). While replacing sugars with artificial sweeteners is a common mitigation strategy, multisensory integration techniques may also improve sweetness perception by modulating other sensory attributes (Hutchings et al., 2019). Common strategies involve changes to foods' intrinsic properties, such as adding aromas or manipulating products' colors. For example, adding vanilla aroma to milk desserts was shown to be an effective strategy for mitigating the effects of sugar reduction (Alcaire et al., 2017). Likewise, adding red coloring to aqueous solutions led to higher sweet taste intensity ratings (Hidaka & Shimoda, 2014; for a discussion of mixed findings in color-taste associations, see Spence, 2019).

The multisensory influences that shape taste perception do not pertain exclusively to the intrinsic properties of foods. External cues, such as products' packaging, plate ware, or ambient sounds, may also modulate how individuals evaluate the taste of foods and drinks (Wang, Mielby, et al., 2019). The manipulation of auditory cues, such as delivering soundscapes or music during eating, has been termed "sonic seasoning" (Spence et al., 2019a). In this line of research, auditory stimuli are either composed or selected to match a given taste or flavor sensation (e.g., a "sweet" ballad). In turn, the congruent pairing of auditory and gustatory stimuli (e.g., a sweet dessert and a "sweet" ballad) enhances or emphasizes the sensory properties of foods and drinks. One pivotal study in the field found that playing a soundtrack congruent with sweet taste enhanced the perceived sweetness of cinder toffee, whereas a "bitter" soundtrack enhanced its bitterness (Crisinel et al., 2012). This seems consistent with the view that attributes of the sonic atmosphere may be "transferred" to the evaluation of the product being tasted. Thus, the crossmodal associations of a soundtrack may accentuate (or suppress) certain sensory attributes of foods, while the feelings about these soundtracks are likely to contribute to the overall hedonic experience (for a discussion of the sensation transfer account, see Spence et al., 2019b)

A growing body of research has since sought to explore the role of musical stimuli in shaping the eating/drinking experience. A large portion of this literature has tested the effect of music in enhancing the taste of alcoholic beverages (e.g., beers, wines) and highly palatable food products (e.g., chocolate, gelati; for a review, see Spence et al., 2019a). While the results in this regard seem promising, it is yet unclear whether music can adequately enhance the acceptance of healthier foods, such as vegetables or low-sugar products. If music can effectively enhance sweet taste perception across food categories, then audition could add to the existing multimodal compensatory strategies for sugar reduction.

In this experiment, we sought to extend the current evidence on sonic seasoning by testing the effect of a "sweet" soundtrack on the sensory perception and acceptance of products varying in sugar content. In the first task, participants tasted two vegetables varying in sweetness (carrots and cucumbers) while listening to a high “sweetness” (vs. low “sweetness”) soundtrack (HS and LS, respectively). The second task consisted of a replication, with the same participants tasting regular and 0% sugar cookies. We hypothesized that HS music would enhance the perceived sweetness of vegetables and cookies compared to the LS (H1). Since sweetness is a commonly desirable attribute, we hypothesized that products under the HS (vs. LS) condition would be liked more (H2) and lead to greater intentions of consuming that product again in the future (H3).

2. Methods

2.1. Participants

A total of 106 participants volunteered to take part in this study. The sample, aged 18-62 (*M* = 26.33, *SD* = 10.26), included 68 participants who identified as women, 35 as men, and three as non-binary. Most participants (66%) reported normal weight (BMI = 18.5-24.9). On average, liking (*M* = 6.89, *SD* = 2.26) and frequency of consumption of sweet foods (*M* = 6.17, *SD* = 2.22) were high. Participants were recruited via internal university communication channels (to the academic community), and external promotion means, including press articles and social media (e.g., LinkedIn, Facebook). Retail vouchers were used as incentives for participation.

2.2. Design

This study consisted of a 2 (soundtrack: high sweetness, low sweetness) x 2 (product: cookies, vegetables) x 2 (sugar level: high, low) full factorial within-participants design.

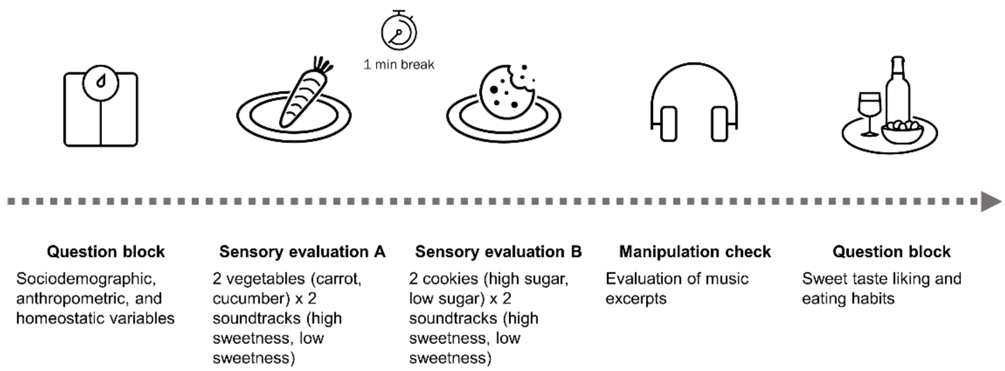
2.3. Study materials and procedures

The study was approved by the ethics committee of Iscte – Instituto Universitário de Lisboa (Approval #117/2020) and was conducted according to international guidelines for research with human participants (Declaration of Helsinki). Communication materials (e.g., study website) specified that the study involved food ingestion, and participants were encouraged to contact the research team in case they suffered from any allergy, intolerance, or other dietary restrictions. This information was provided again orally and in the informed consent form before beginning the experiment.

Participants were instructed to refrain from eating, drinking coffee, brushing their teeth, or smoking the hour prior to participation. Data collection took place at the university lab, equipped with computers and headphones. Participants were told they would be asked to evaluate different food samples while listening to music. Then, they were asked to put the headphones on and follow the instructions provided on the computer. For this purpose, a web-based survey was programmed in Qualtrics (see Figure 1 for an overview). The survey was programmed to play the soundtracks automatically, and the sound player controls remained hidden from participants. All devices were kept at the same comfortable volume level.

Figure 1

Overview of the Experimental Tasks



After providing informed consent, participants were asked to fill out their sociodemographic information (e.g., age, gender) along with self-report measures of anthropometric (height, weight) and homeostatic variables (thirst, hunger). Two blocks of sample evaluations followed. In the first block, participants tasted samples of a sweet vegetable (baby carrot) and a less sweet vegetable (baby cucumber). Both vegetables were tasted twice, each time paired with a different soundtrack. The four vegetable-soundtrack pairs were presented in counterbalanced order. The same procedure was followed in the second block of sample evaluation, this time with two versions of a chocolate chip cookie with different sugar contents. After tasting each sample, participants were instructed to drink water to cleanse the palate. Moreover, the two evaluation blocks were separated by a 1-minute break in which participants saw a 60s video-timer.

In the following block, the two soundtracks that were played during the tasting task were presented again (in random order) to be evaluated in taste (sweetness) and affective (valence, arousal) dimensions. The last section of the survey comprised measures of sweet taste liking and eating habits.

2.2.1. Food samples

Baby carrots and baby cucumbers were chosen as more sweet and less sweet vegetables, respectively. According to the Table of Food Composition 5.0. (INSA, 2021), raw baby carrots present an average of 4.8g of sugar per 100g, whereas raw cucumbers present an average of 1.6g of sugar per 100g. Both vegetables were cut into pieces of approximately 3cm and served raw at room temperature.

Two versions of commercially available chocolate chip mini cookies were selected for this study. According to the manufacturer, the standard cookies contain about 30% sugar, whereas the 0% sugar mini cookies present < 0.5g sugar per 100g of product. Each cookie has an approximate size of 2.5cm in diameter. All samples were presented in round disposable white paper plates, identified with three-digit codes.

2.2.2. Musical stimuli

Two instrumental soundtracks were selected from the Taste & Affect Music Database (Guedes et al., 2022). The high sweetness soundtrack ("Fruit of Lore", 80 BPM) was evaluated as sweet by 80.52% of the sample in the norming study, whereas the low sweetness soundtrack ("Walk of Destiny", 152 BPM) was rated as sweet by only 7.02% of participants[1]. The soundtracks were chosen to reflect contrasting sweet taste correspondences but approximate valence ratings (both excerpts were scored "High" in valence in the norming study). These music excerpts were not marketed to the general public and, thus, were unfamiliar to the participants.

2.3. Measures

The food samples were evaluated in several sensory and hedonic attributes using 9-point scales. Both product categories (vegetables and cookies) were evaluated in sweetness (1 = *Not sweet* to 9 = *Highly sweet*) and liking (1 = *I don't like it at all* to 9 = *I like it very much*). The sample evaluation task also included attributes unrelated to the experimental manipulation (e.g., bitterness, healthfulness, crunchiness) to keep participants blind to the goal of the study. All items were presented in random order. At the end of each evaluation, participants were asked to indicate the likelihood of consuming that product again in the future, using a continuous scale ranging from 0% to 100%.

As a manipulation check, we also included a soundtrack evaluation task, asking participants to rate each excerpt on sweetness (1 = *Not sweet at all* to 9 = *Very sweet*), valence (1 = *Not pleasant at all* to 9 = *Very pleasant*), and arousal (1 = *Not arousing at all* to 9 = *Very*

[1] Basic taste correspondences were evaluated based on a forced-choice paradigm. Alternatives were sweet, bitter, salty, and sour.

arousing) using 9-point scales. The last block of questions asked about participants' sweet taste liking and consumption (9-point scales).

2.4. Data analyses

All analyses were conducted with IBM SPSS Statistics v26. First, participants' evaluations of the HS and LS soundtracks were compared with Paired Samples *t*-tests. The two soundtracks were analyzed as HS and LS stimuli based on the group average. Thus, no observations were removed based on individual ratings on the manipulation check.

Three repeated-measures ANOVA models were conducted separately for each dependent variable, namely, sweetness ratings, liking, and future consumption intentions. The models included soundtrack (high sweetness, low sweetness), food category (vegetables, cookies), and sugar level (high, low) as within-subject factors. All main effects are reported in Table 1. Interaction effects were analyzed and reported when significant ($p \leq .05$).

3. Results

All participants reported compliance with the inclusion criteria (e.g., avoiding smoking, drinking coffee). Thus, all were retained for analysis.

3.1. Evaluation of high sweetness and low sweetness soundtracks

Congruently with the results of the norming study, the two soundtracks differed in sweetness ratings, such that the HS soundtrack was evaluated as sweeter (M = 6.90, SD = 1.77) than the LS soundtrack (M = 2.53, SD = 1.46), $t(106) = 19.56$, $p < .001$. Both soundtracks were rated high in valence, with higher mean ratings for the HS (M = 7.26, SD = 1.77) compared to the LS soundtrack (M = 5.37, SD = 1.95), $t(106) = 7.98$, $p < .001$. The LS soundtrack was evaluated as more arousing (M = 7.87, SD = 1.44) than the HS soundtrack (M = 3.73, SD = 2.06), $t(106) = 17.87$, $p < .001$.

3.2. Influence of soundtrack condition on sweet taste ratings

Descriptive statistics (means, standard errors) and the results of the within-subjects analysis of variance are presented in Table 1. A main effect of soundtrack condition showed that music had a significant influence on sweetness ratings, $F(1,105) = 8.85$, $p = .004$, $\eta_p^2 = 0.08$. Overall, and as hypothesized (H1), food products were rated as sweeter in the HS condition compared to the LS condition. No significant interactions were observed between soundtrack condition and either product type (cookies vs. vegetables), $F(1,105) = 0.02$, $p = .893$, $\eta_p^2 = 0.00$, or sweetness level (sweeter cookie/vegetable vs. less sweet cookie/vegetable), $F(1,105) = 3.33$, $p = .071$ $\eta_p^2 = 0.03$. In the latter case, the trend pointed to a larger effect of music in the less sweet ($M_{HS} = 4.75$; $M_{LS} = 4.35$) than in the sweeter ($M_{HS} = 6.22$; $M_{LS} = 6.09$) samples. The main effects of product type and sugar level were also significant (see Table 1).

3.3. Influence of soundtrack condition on liking

A significant main effect of soundtrack was observed on liking ratings of the samples, $F(1,105) = 8.03$, $p = .006$, $\eta_p^2 = 0.07$, supporting H2. On average, participants reported liking the samples more when listening to the HS soundtrack than the LS soundtrack. No significant interactions were observed with product type or products' sugar level (all $p > .414$). Thus, it seems that the effect of soundtracks on the hedonic ratings was not dependent on the products' characteristics. The main effects of product type and sugar level are reported in Table 1.

3.4. Influence of soundtrack condition on intentions of future consumption

The main effect of soundtrack was also observed in future consumption intentions, $F(1,105) = 6.54$, $p = .012$, $\eta_p^2 = 0.06$, supporting H3. Participants reported a higher likelihood of future consumption in the HS soundtrack condition compared to the LS condition. The effect did not depend on product type or sugar level, as seen by the absence of significant interactions with these variables (all $p > .160$). A main effect of sugar level (but not product type) was also observed (see Table 1).

Table 1

Means, Standard Errors, and Main Effects of Soundtrack Condition (A), Product (B), and Sugar Level (C) on Sweetness, Liking, and Intentions of Future Consumption

(A) Soundtrack	HS		LS			
	M	*SE*	*M*	*SE*	*F*(1,105)	η_p^2
Sweetness	5.48	0.11	5.22	0.09	8.85**	0.08
Liking	6.7	0.12	6.51	0.13	8.03**	0.07
Future intentions	70.8	1.71	69	1.78	6.54*	0.06
(B) Product	**Cookies**		**Vegetables**			
	M	*SE*	*M*	*SE*	*F*(1,105)	η_p^2
Sweetness	6.52	0.12	4.18	0.13	179.75***	0.63
Liking	7.11	0.15	6.09	0.18	19.66***	0.16
Future intentions	70.99	2.17	68.81	2.43	0.50	0.01
(C) Sugar level	**High**		**Low**			
	M	*SE*	*M*	*SE*	*F*(1,105)	η_p^2
Sweetness	6.15	0.10	4.55	0.12	143.85***	0.58
Liking	7.09	0.12	6.11	0.15	50.29***	0.32
Future intentions	75.26	1.75	64.5	2.04	41.96***	0.29

Note. HS = High sweetness soundtrack, LS = Low sweetness soundtrack

* $p < .050$; ** $p < .010$; *** $p < .001$

4. Discussion

Multisensory integration strategies have been previously put forward as potential pathways to compensate for sugar reduction. In this study, we tested the feasibility of using music-taste interactions to enhance sweet taste perception of products varying in sweetness levels. Two product categories (vegetables and cookies) with higher and lower sugar levels were tasted along with high "sweetness" and low "sweetness" soundtracks.

Results showed that music significantly influenced the perception and acceptance of the samples. The HS soundtrack resulted in higher sweetness ratings, as well as higher liking and more favorable intentions towards future consumption. These results are in line with previous studies showing an effect of music on sweet taste intensity ratings. Notably, this study also adds to previous findings showing that music may impact taste perception even when soundtracks are incidentally (rather than purposely) associated with taste attributes

(Hauck & Hecht, 2019; Wang, Mesz, et al., 2019). The music excerpts explored here are part of a validated database of instrumental soundtracks that showed reliable associations with basic tastes, even though they were not composed with crossmodal goals in mind (Guedes et al., 2022). Thus, these findings may help shed light on how background music that could be found in meal settings (e.g., restaurants, cafeterias) may spark sound-taste correspondences and influence eating behavior.

The results presented here attest that the two soundtracks conveyed the taste sensations they were expected to express according to the validation data. The HS soundtracks presented higher sweetness ratings compared to the LS soundtracks, and this difference was the largest among all rating dimensions. The two soundtracks also differed significantly on affective ratings, which leaves the question of whether affect may contribute to sonic seasoning effects. Indeed, previous studies have shown that listening to liked music may impact sweet taste perception, for instance, in gelati (Kantono et al., 2016, 2019), whereas disliked music may enhance bitterness attributes. Recently, it has been argued that emotionality may be more impactful for the taste experience than crossmodal attributes, such as softness/hardness (Reinoso-Carvalho et al., 2020). Although differences in the affective ratings of the soundtracks were observed, it is unclear whether these reflected actual mood changes (as “perceived” and “felt” affective dimensions are not entirely equivalent, e.g., Guedes et al., 2022). This may be a relevant distinction since mood changes induced by music (beyond “conceptual” affective associations alone) seem to contribute to shaping the gustatory experience (Kantono et al., 2019).

While this question is beyond the scope of the present study, we should note that the soundtracks tested here differed more strongly in taste correspondences than in valence associations and their effect, in turn, was more evident in taste attributes than in liking of the samples. This is consistent with the view that music attributes may be mapped onto gustatory stimuli in meaningful ways (North, 2012). Overall, these findings support the notion that hearing and, particularly, listening to music may impact taste perception. Without a "neutral" control condition, however, it is unclear whether the crossmodal effects on taste were due to the enhancing effect of a highly "sweet" soundtrack or a buffering effect of a less "sweet" stimulus. Thus, the inclusion of neutral conditions could help disentangle these possibly concurrent effects in future studies. We should also note that, in this context, high (vs. low) sweetness refers to average ratings, based on sample consensus, rather than individual judgements. Thus, individual differences in soundtrack evaluation were not taken into account when interpreting these results.

In both sets of products (vegetables and cookies), participants showed a higher preference for the sweeter versions (carrots and regular cookies), echoing the challenges of building adherence to products with lower sugar levels (de Souza et al., 2021; Hutchings et al., 2019). In the case of the cookies tested here, the 0% sugar version included an undisclosed amount of sweetener (maltitol) in its formulation. In any case – and as intended – these samples were still subjectively perceived as less sweet, according to participants' ratings. From that standpoint, the current findings suggest that crossmodal correspondences may contribute to minimizing the sensory and hedonic disadvantages of less sweet products. Furthermore, to our best knowledge, this was the first time a sonic seasoning approach was applied to promote vegetable acceptance. Extending these findings to a greater variety of healthy products (e.g., fruits and vegetables) may prove advantageous for promoting adherence to healthier eating with lesser compromises for enjoyment. Although adding a sweet soundtrack to the eating environment is hardly comparable to adding a spoonful of sugar, the crossmodal interactions between audition and taste may open a promising route for enhancing taste perception, either alone or as part of broader multisensory interventions.

5. Conclusions

This study presents new evidence on the contributions of audition to sweet taste perception and overall acceptance of healthier products. Results support the use of sonic seasoning principles with products with varying sugar levels, such as sweeter and less sweet vegetables and cookies. The study of crossmodal correspondences may offer relevant insights on how to support sugar reduction while minimizing the sensory and hedonic consequences of lower sugar levels. These findings could inform future interventions in naturalistic settings, namely in planning more appropriate soundscapes for restaurants or cafeterias where healthier eating is to be encouraged.

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Declarations of interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

Ethical Statement

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

CRediT author statement

DG: Conceptualization; Investigation; Formal analysis; Methodology; Writing - original draft.

MP: Conceptualization; Methodology; Writing - review & editing.

MVG: Conceptualization; Methodology; Writing - review & editing.

EL: Conceptualization; Methodology; Writing - review & editing.

References

Alcaire, F., Antúnez, L., Vidal, L., Giménez, A., & Ares, G. (2017). Aroma-related cross-modal interactions for sugar reduction in milk desserts: Influence on consumer perception. *Food Research International*, *97*, 45–50. https://doi.org/10.1016/j.foodres.2017.02.019

Crisinel, A.-S., Cosser, S., King, S., Jones, R., Petrie, J., & Spence, C. (2012). A bittersweet symphony: Systematically modulating the taste of food by changing the sonic properties of the soundtrack playing in the background. *Food Quality and Preference*, *24*, 201–204. https://doi.org/10.1016/j.foodqual.2011.08.009

de Souza, L. B. A., Pinto, V. R. A., Nascimento, L. G. L., Stephani, R., de Carvalho, A. F., & Perrone, Í. T. (2021). Low-sugar strawberry yogurt: Hedonic thresholds and expectations. *Journal of Sensory Studies*, *36*(3), 1–15. https://doi.org/10.1111/joss.12643

Guedes, D., Prada, M., Garrido, M. V., & Lamy, E. (2022). The taste & affect music database: Subjective rating norms for a new set of musical stimuli. *Behavior Research Methods*. https://doi.org/10.3758/s13428-022-01862-z

Hauck, P., & Hecht, H. (2019). Having a drink with Tchaikovsky: The crossmodal influence of background music on the taste of beverages. *Multisensory Research*, *32*(1), 1–24. https://doi.org/10.1163/22134808-20181321

Hidaka, S., & Shimoda, K. (2014). Investigation of the effects of color on judgments of sweetness using a taste adaptation method. *Multisensory Research*, *27*(3–4), 189–205. https://doi.org/10.1163/22134808-00002455

Hutchings, S. C., Low, J. Y. Q., & Keast, R. S. J. (2019). Sugar reduction without compromising sensory perception. An impossible dream? *Critical Reviews in Food Science and Nutrition*, *59*(14), 2287–2307. https://doi.org/10.1080/10408398.2018.1450214

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 and 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

Mennella, J. A., & Bobowski, N. K. (2015). The sweetness and bitterness of childhood: Insights from basic research on taste preferences. *Physiology & Behavior*, *152*, 502–507. https://doi.org/10.1016/j.physbeh.2015.05.015

North, A. C. (2012). The effect of background music on the taste of wine. *British Journal of Psychology*, *103*(3), 293–301. https://doi.org/10.0.4.87/j.2044-8295.2011.02072.x

OECD/FAO. (2020). *OECD-FAO Agricultural Outlook 2020-2029*. FAO/OECD Publishing. https://doi.org/10.1787/1112c23b-en.

Prada, M., Saraiva, M., Viegas, C., Cavalheiro, B. P., & Vaz Garrido, M. (2022). Relationship between objective and perceived sugar content on consumers perceptions about breakfast cereals. *Food Quality and Preference*, *96*, 104387. https://doi.org/10.1016/j.foodqual.2021.104387

Reinoso-Carvalho, F., Gunn, L. H., ter Horst, E., & Spence, C. (2020). Blending emotions and cross-modality in sonic seasoning: Towards greater applicability in the design of multisensory food experiences. *Foods*, *9*(12), 1876. https://doi.org/10.3390/foods9121876

Spence, C. (2019). On the relationship(s) between color and taste/flavor. *Experimental Psychology*, *66*(2), 99–111. https://doi.org/10.1027/1618-3169/a000439

Spence, C., Reinoso-Carvalho, F., Velasco, C., & Wang, Q. J. (2019a). Extrinsic auditory contributions to food perception & consumer behaviour: An interdisciplinary review. *Multisensory Research*, *32*(4/5), 275–318. https://doi.org/10.0.4.139/22134808-20191403

Spence, C., Reinoso-Carvalho, F., Velasco, C., & Wang, Q. J. (2019b). *Auditory contributions to* *food perception and consumer behaviour*. Brill. https://doi.org/10.1163/9789004416307

Wang, Q. J., Mesz, B., Riera, P., Trevisan, M., Sigman, M., Guha, A., & Spence, C. (2019). Analysing the impact of music on the perception of red wine via temporal dominance of sensations. *Multisensory Research*, *32*(4–5), 455–472. https://doi.org/10.1163/22134808-20191401

Wang, Q. J., Mielby, L. A., Junge, J. Y., Bertelsen, A. S., Kidmose, U., Spence, C., & Byrne, D. V. (2019). The role of intrinsic and extrinsic sensory factors in sweetness perception of food and beverages: A review. *Foods*, *8*(6). https://doi.org/10.3390/foods8060211

Wansink, B., & Sangerman, C. (2000). Engineering comfort foods. *American Demographics*, *19*(12), 53–58. https://doi.org/10.2139/ssrn.2473679

World Health Organization. (2015). *Guideline: Sugars intake for adults and children*. World Health Organization.