Current Research in Food Science 6 (2023) 100508

Contents lists available at ScienceDirect

Current Research in Food Science

journal homepage: www.sciencedirect.com/journal/current-research-in-food-science

How do ethnically congruent music and meal drive food choices?

Dorina Szakál [a,b], Xu Cao [c], Orsolya Fehér [b], Attila Gere [c,*]

[a] Department of Hospitality, Faculty of Commerce, Hospitality and Tourism, Budapest Business School, Alkotmány utca 9-11, H-1045, Budapest, Hungary
[b] Institute of Agribusiness, Hungarian University of Agriculture and Life Sciences, Villányi út 29-31, H-1118, Budapest, Hungary
[c] Institute of Food Science and Technology, Hungarian University of Agriculture and Life Sciences, Villányi út 29-31, H-1118, Budapest, Hungary

A R T I C L E I N F O

Handling Editor: Dr. Xing Chen

Keywords:
Eye-tracking
Consumer decision
Music
Sensory marketing
Ethnic group

A B S T R A C T

Playing ethnic music in restaurants increases consumer experience. Studies show, furthermore, that ethnic congruence of music and food affects food selection but not the liking of customers. An eye-tracking study was completed with 104 participants to uncover if there is an effect of ethnic music on selecting ethnic foods. German, Hungarian, Italian, and Spanish ethnic music was played while participants choose congruent starters, main dishes, and desserts. Results show that visual attention decreased when any background music was played. However, when played, the highest visual attention was recorded during Spanish music. Similarly, the most visual attention was recorded on Spanish dishes. Food choice frequencies showed no differences among the four nations. However, after aggregating German-Hungarian and Italian-Spanish music and dishes, it turned out that participants chose congruent music and food. Choice predictions were also completed on data with and without ethnic music. The performance of prediction models significantly increased when music was played. These findings highlight a clear link between music and food choices, and that music helped participants complete their choices and decide faster.

1. Introduction

Eye movement monitoring is widely used around the world. It has been published in a number of scientific fields, such as the film industry (Hammerschmidt and Wollner, 2018), psychology (Orquin and Mueller Loose, 2013), and the food industry (Peng-Li et al., 2020). The study of visual attention through eye-tracker has a long tradition in many areas of marketing knowledge, especially in the field of consumer behavior. Research on visual attention can help to understand consumer decision-making in the process of searching for information, evaluating alternatives, and making choices.

The perception and evaluation of food is a multifaceted construct process. Individual and cultural differences, and external environmental factors, such as background music, odor, and visual impression can significantly influence a myriad of subconscious consumer behaviors (Biswas et al., 2019; Huang and Labroo, 2020; Jeong and Lee, 2021; Pantoja and Borges, 2021; Peng-Li et al., 2022; Szakál et al., 2022), which is described by Li (2017) as "*working or existing outside of consciousness*" on a strict psychological sense; hence, subconscious behavior is defined as an action or response in a subconscious state. Among the elements of the store atmosphere, there has been research on music (Cho et al., 2020; Cui et al., 2021), smells (Errajaa et al., 2020; Lwin et al., 2016; Szakál et al., 2022) or colours (Bytyçi, 2020; Cho et al., 2020; Golnar-Nik et al., 2019). It has been shown that background music interferes with tasting (Reinoso Carvalho et al., 2016). Additionally, music is used to influence consumers' purchase behaviours and/or food perceptions in different ways (Spence et al., 2019). In retails - or even in hotels and restaurants- there is a strong emphasis on their use and there are even brands that can be identified by a melody (Krishna, 2012). Furthermore, for online commerce, the type of ambient music used has an impact on positive or negative perspectives. Research by Anwar et al. (2020) finds that proper music should be chosen to encourage shoppers to spend more time in the online store, increase repurchases and revisits, thus helping retailers to make the shopping environment more attractive.

In laboratory situation, background music can affect performance in cognitive tasks (memory, attention, and comprehension), both positively and negatively. Used extensively as an advertising tool, it may also affect marketing strategies, comprehension, and consumer choices. Background music can influence learning (Aheadi et al., 2010; De Groot, 2006), working memory and recall (Alley and Greene, 2008; Cassidy and Macdonald, 2007) performance while working on tests (Avila et al.,

* Corresponding author.
E-mail address: gere.attila@uni-mate.hu (A. Gere).

https://doi.org/10.1016/j.crfs.2023.100508
Received 13 February 2023; Received in revised form 3 April 2023; Accepted 24 April 2023
Available online 25 April 2023

2012; Patston and Toppett, 2011) and attention in cognitive monitoring tasks (Beanland et al., 2011; Olivers and Nieuwenhuis, 2005). The mediating role of emotions was documented in some experiments and positive valence mediated the relationship between music genre and sweet and healthier savory foods (Motoki et al., 2022). What is more, from a tempo perspective, fast music is more effective to stimulate positive taste expectations than soothing music and it enhances impatience (Kim and Zauberman, 2019; Pantoja and Borges, 2021). Besides, music is positively related to food intake with a small effect size (Cui et al., 2021). In congruence with previous studies, Peng-Li et al. (2021) conducted a comparison study through the Regulation of Craving (ROC) task and confirmed that ambient music influences regulating cravings and decision-making.

Background music triggers specific emotional responses and was directly and cross-culturally linked with food. A clear ethnic congruency effect is documented between music and food choice across cultures (Peng -Li et al., 2020a,b). Western food was chosen more when Western music was playing, and Eastern food was preferred when Eastern music was playing. Correspondingly, Huang and Labroo (2020)conducted empirical research and found that the way background music affects visual attention varies by culture through playing Western and Eastern music while Chinese and Danish participants made their food selections. Music can have a significant impact on consumers' explicit (conscious) and implicit (nonconscious) behaviors (Braunstein et al., 2017). Higher-pitched sounds (*e.g.*, when constituting part of voiceover ads) can increase Japanese consumers' purchase intention of sweet food, when compared to their purchase intention for bitter food (Motoki et al., 2022).

Music psychology (volume, tempo, genre, pitch, and compatibility) have varied effects on consumers' food choices. The effects of background music on food preferences were dependent on the interaction between music genre, food type, and taste. Listening to Jazz and Classical music increased people's preferences for healthy savoury foods (*e.g.*, vegetable sandwich) as compared to Rock/Metal music. Listening to Rock/Metal, Hip-hop, and Jazz music increased people's preferences for indulgent savoury foods (*e.g.*, a beef sandwich) as compared to Classical music. Additionally, listening to Classical music increased people's choice for both healthier and indulgent sweet foods as compared with the other musical genres (Motoki et al., 2022).

Background music had a significant impact on the sensory evaluation of alcoholic beverages (Damen et al., 2021; De Luca et al., 2019; Sassenberg et al., 2022). According to the results of one now-classic study, playing French (German) music in the wine aisle of a British supermarket dramatically increased the choice of French (German) wine (North et al., 1997). Moreover, there are significant differences in consumers' sensory perceptions among different background music genres. Craft beer was more popular when listening to classic rock compared to pop, soft rock, and sertanejo (Paulo et al., 2022). Some musical genres are effective in influencing the experience of tasting and consuming food and beverages. In the evaluation of New England IPA-style craft beer, bitterness was present in all musical genres. However, for each genre of music, participants reported different feelings. In all auditory environments, the bitter feeling persisted. Nonetheless, diverse sensations were observed for each musical genre including fruity flavor for classic rock, refreshing for pop, lightness for soft rock, and astringency for sertanejo.

Ambient music particularly is a common feature of restaurants and retail stores, which is an important part of marketing communication. However, its significance as a marketing tool has not been widely recognized. Nevertheless, the effects of ethnic music on meal choice have not yet been composed nor explored in connection to its implicit behavior effects. Therefore, the present study aims to examine whether the ambient music of different nations can influence consumers' meal selection. Although numerous studies have examined the effects of ambient music on food preferences, few studies focus on the effects of ethnic music on meal choice. Restaurants and retail stores can take the benefits of background music as an effective marketing tool. Our exploratory research aims to help learn more about the impact of music on consumer decision-making. Specifically, these questions will be examined in this study.

(1) Can ethnic music influence consumers' meal decisions? Does ethnic music have effects on visual attention?
(2) Does ethnic music have any effect on visual attention?
(3) Is there an interaction between congruent music and food?
(4) Is there any association between cultures with low cultural distances?

2. Materials and methods

2.1. Participants

A total of 119 participants took part in the main study. Fifteen participants were removed from the analysis due to unacceptable eye-tracking quality <80%. The remaining 104 participants (44 male and 60 female) were divided into two groups: the control group (those who did not listen to music during the measurement) consisted of 52 participants (mean age ± SD = 22.08 ± 2.64 years) and the music group (those who listened to music during the measurement) consisted of 52 participants (mean age ± SD = 23.29 ± 5.84 years). All of the selected participants were Hungarian University students at the Hungarian University of Agriculture and Life Sciences. Detailed demographic information of the participants is given in Table 1. The measurement was carried out in one of the rooms of the Buda Campus of the Hungarian University of Agricultural and Life Sciences, which was approximately 18 m^2 (6 m long, 3 m wide, and 2.60 m high) and located in a quiet and central part of the university. The computer was placed in the middle of the room. The light in the room was provided by an LED panel (6500 K, 1600 lm) mounted on the ceiling above the table. Among the visual impairments, farsightedness and nearsightedness were the most common as five participants reported squinting and three participants were colour-blind, 12 participants wore contact lenses, and 32 wore glasses. At the end of the questionnaire, participants who had listened to music during the survey were asked how much they liked it (Fig. 1).

2.2. Eye-tracker and software

We follow the reporting guidelines, provided by Fiedler et al. (2020), to describe the eye-tracking process. Eye movements were tracked with Tobii Pro X2-60 (Tobii Pro AB, Danderyd, Sweden). The image sequences were presented with Tobii Pro Lab v.1.171 (Tobii Pro AB, Danderyd, Sweden) software. The eye-tracking creates a near-infrared pattern on the eye and then captures high-resolution images of it. To compute the gaze point and position of the eyes utilizing a complex 3D eye model technique, the image processing algorithms look for distinctive details in the user's eyes and reflection patterns. The first fixation duration, fixation duration, and fixation count were used from a huge quantity of data that was defined and extracted by the software. This type of eye-tracker is small, unobtrusive, allows a certain freedom of movement of the head, and does not disturb the participant. The appropriate distance between the camera and the eye is 60–65 cm, and the ideal viewing angle is ≤ 65°.

2.3. Visual stimuli

Before the final selection of visual stimuli, a pre-test was conducted with 39 participants (similar in age to the participants of the main test). In the pre-test, participants were asked to inspect five from each course (starters, main courses, and desserts) of each nation using paper and pencil interviewing (PAPI). The dishes with the highest number of choices were included in the final set of images.

Four different sets of images were shown to participants, out of which the first were the trial slides. The structure of the remaining three

Table 1
Demographic profile of the participants by sound and soundless conditions (%)..

			control	music
gender		male	23.0	19.0
		female	27.0	31.0
education	undergraduate	male	19.2	17.3
	graduate		3.8	1.9
	undergraduate	female	20.2	25.0
	graduate		6.7	5.8
place of living	small town	male	3.8	4.8
	rural		1.9	3.8
	large city		17.3	10.6
	small town	female	8.7	9.6
	rural		6.7	2.9
	large city		11.5	18.3
visual aid	contact lenses	male	1.0	2.9
	glasses		4.8	4.8
	contact lenses	female	1.9	6.7
	glasses		7.7	9.6

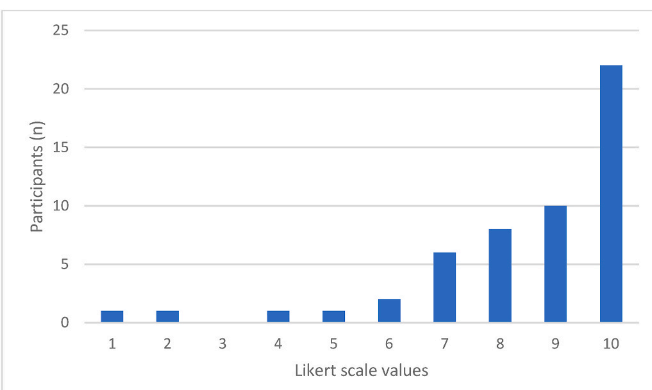

Fig. 1. Ten-point Likert scale scores for preference for music.

choice sets was identical, but the location of the products was randomized. The image sets included starters, main courses, and desserts (Fig. 2), which are traditional for four different nations (German, Hungarian, Italian, and Spanish).

Before each picture, a fixation cross was shown on the screen for 2 seconds, so that the gaze of participants was centered on each picture. Visual stimuli were presented on an LG W2452V-PF 24″ Full HD LCD monitor with a resolution of 1366 × 768. In order to avoid overlap, the distance between AOIs (areas of interest) was maximized. We applied an Identification by Velocity Threshold (I-VT) filtering method that used interpolation between gaps (75 ms), noise reduction (median), a velocity threshold of 30°/s, merged adjacent fixations (<0.5°) between fixations (<75 ms) and discarded short fixations (<60 ms).

2.4. Auditory stimuli

As the research was designed to investigate the effect of music on

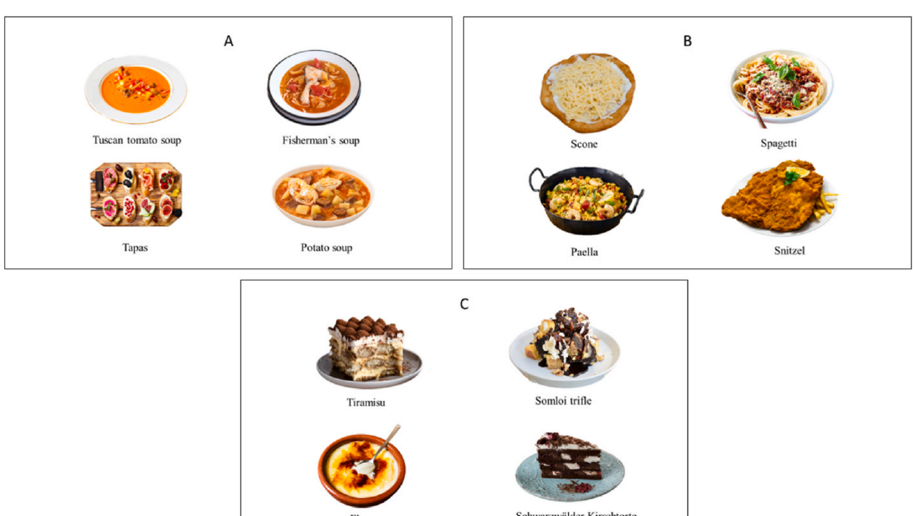

Fig. 2. Images of the appetizers (A), main courses (B) and desserts (C) used in the measurement.

decision-making, the music was defined after visiting ethnic restaurants in Budapest, Hungary. The tempo of each auditory stimulus was as follows: Hungarian music 112 bpm (moderato), German music 91 bpm (andante), Spanish music 80 bpm (andante), and Italian music 96 bpm (andante). The music from four nations (German, Hungarian, Italian, and Spanish) was played on a Philips TAS6305/00 Bluetooth speaker (Eindhoven, The Netherlands) at approximately 60 dB. Before the measurements, 39 people (the same people who had taken the pre-test on visual stimuli) were asked to listen to the auditory stimuli and to give their opinion on which nation's music they heard. About 90% of the participants gave the correct answer. The tracks are available here: https://open.spotify.com/playlist/73qjhvWh9kAJqDQUUuCdvY?si=O-CLATbcTHCTmNx4DeOMWQ&utm_source=copy-link&fbclid=IwAR1CzmiCtBAaYJocI1LG1eUZ4Scz755slJTl68I3oBcrr3kqA5ojG5iz4oo&nd=1.

2.5. Design and procedure

The study included a control group (soundless) and a sound group. The control group (soundless) consisted of 52 participants, whose eye movements were measured in a soundless environment. Then, we repeated the measurement with 52 participants, but this time each participant was randomly assigned to one ethnic music. The mechanism of measurement was the same for the two groups, the only difference being music. As a first step in the measurement, we asked participants to sit down in front of the computer in a comfortable position, and then asked them not to change their position during the measurement. They were then informed of the measurement procedure. The next step was to calibrate the eye-tracker. After successful calibration, we started the timelines on the screen. First, a screen with instructions was shown to the participants. After participants had read the text, they moved on to the next slide by pressing a key on the keyboard. Afterward, a trial slide appeared, on which foods other than the subject of the measurement were presented, such as Nestlé Chocapic, Nestlé Cini Minis, Nestlé Cookie Crisp, and Nestlé Nesquik. The purpose of this slide was to familiarize participants with the procedure. The participants were asked to choose one they liked the most from the four products and then press a key on the keyboard. The mouse cursor then appeared on the screen so they could click on the product they liked the most. Once they had clicked, they had to press a key on the keyboard again to move on to the next set of images. A fixation cross was displayed for 2 seconds before each choice set, but there was no time limit on the choice. At the end of the procedure, participants filled a short questionnaire about demographic information and music preferences.

2.6. Data analysis

Eye-tracking data was recorded using Tobii Pro Lab v.1.171 (Tobii Pro AB, Danderyd, Sweden) software. The following eye-tracking parameters were extracted and used for the data analysis:

- Time To First Fixation (TTFF, time elapsed between the appearance of stimuli and the user fixating his/her gaze first on an alternative in seconds);
- First Fixation Duration (FFD, length of the first fixation on an alternative, in seconds);
- Fixation Duration (FD, total length of fixations on an alternative, in seconds);
- Fixation Count (FC, number of fixations on an alternative, count);
- Dwell Duration (DD, time elapsed between the user's first fixation on a product and the next fixation outside the product, in seconds) and
- Dwell Count (DC, number of "visits" on an alternative, count).

Principal component analysis, Mann-Whitney *U* test, and analysis of variance were run using XLSTAT Version 16.0. (Addinsoft, Paris, France). Classification models were trained using R-project Version R-4.2.1 (R Core Team, 2023) and the following packages: linear discriminant analysis: `MASS`, artificial neural network: `nnet`, random forest: `randomForest`, support vector machine: `e1071` and k-nearest neighbour classifier: `class`. The following performance metrics were calculated using the library `caret`:

All parameters were calculated for all classes.

Models were created on the eye-tracking data obtained from the control group (ns) and sound group (s). Eye-tracking parameters were set as independent variables and the choice was used as the class to be predicted. Therefore, altogether eight models were trained and tested, four on the control data and four on the data of the sound group. Models have been compared using the sum of ranking differences (SRD) method. SRD is a fast, easy-to-use technique developed for model comparisons. SRD is a multicriteria decision-making (MCDM) tool, as it takes several input variables (features) and ranks multiple models based on these features.

SRD aims to compare the different models to a theoretically best model, which was defined as the maximum value of the features. SRD has multiple other options to define the best theoretical rankings see c. f. (Héberger, 2010). In addition, SRD ranks the models based on their performance metrics; therefore a vector is created for each model containing ranks from 1 to 44, as the 11 features were calculated for all four classes. In the next step, the reference column, containing the theoretically best model (using the row maximums) is rank transformed as well. In the third step, the vectors of the models are subtracted from the reference vector, *e.g.* row-wise absolute rank differences are calculated. In the final step, the row-wise rank differences are summed up for each model giving the sum of the ranking difference (SRD) value. The lower the SRD value, the closer the model to the theoretically best model performance is. A higher SRD value means, however, that the model's performance is worse. The SRD values give not only a clear rank of the models but also characteristic patterns (grouping) that can be observed. The algorithm for the sum of ranking differences was calculated with Microsoft Office Excel 2007 macro retrieved from: http://aki.ttk.mta.hu/srd.

The first validation of the SRD results uses a randomization test, where the distances from random rankings are used. For further information on the comparison of random ranks with random numbers (CRRN), see (Héberger and Kollár-Hunek, 2011). The second validation of the SRD results uses analysis of variance with Factor 1: resampling variant (two levels: contiguous sevenfold resampling–A, random resampling with replacement–B), Factor 2: models (8 levels), and Factor 3: cross-validation variant (3 levels, 5-fold, 7-fold and 10-fold). Further information on the ANOVA validation of SRD is available here (Héberger and Kollár-Hunek, 2019).

3. Results

3.1. Comparison of visual stimuli

Table 2 shows the mean, standard deviation, and *p*-values (Mann-Whitney *U* test) for the sound and soundless groups for each visual parameter. For almost all parameters, the mean and standard deviation decreased with music and the difference was significant except for TTFF. As the images were randomly arranged, the lack of significant differences in TTFF is expected. These results suggest that the presence of music decreased visual attention and participants needed less time to choose one alternative.

3.2. Effect of the type of music

As the tempo of the chosen auditory stimuli differs slightly, the total recording times of participants were compared. One-way analysis of variance (ANOVA) was run with one factor, in which the levels were the four ethnic music. ANOVA revealed that there was no statistically significant difference in the mean total recording times ($F(3, 48) = 1.784$,

Table 2
Mean, standard deviation and *p*-values (Mann-Whitney *U* test) for the sound and soundless groups for each visual parameter.

Variable	Mean	Std. Deviation	p-values
FD |c	0.841	0.650	**< 0.01**
FD |m	0.703	0.588	
FC |c	3.229	1.962	**< 0.05**
FC |m	2.949	1.998	
TTFF |c	0.876	0.679	n.s.
TTFF |m	0.879	0.630	
FFD |c	0.262	0.160	**< 0.01**
FFD |m	0.238	0.146	
DD |c	0.923	0.734	**< 0.01**
DD |m	0.795	0.662	
DC |c	1.628	0.842	**< 0.05**
DC |m	1.491	0.832	

FD: fixation duration, FC: fixation count, TTFF: time to first fixation, DD: dwell duration, DC: dwell count, m: music condition, c: control.

$p = 0.163$). This means that a higher tempo had no effect on visual attention in the presented case.

In the next step, we focused on the sound condition. Table 3 shows the effect of the music of the four nations on each visual parameter. In the case of all dishes, Spanish music scored the highest for almost all parameters, which means that the alternatives received the highest visual attention when Spanish music was played. Italian music had the highest dwell counts, but for Spanish and Italian music there was no significant difference for DC. Except for TTFF, the visual attention was the lowest when Hungarian music was played.

If we look at the results for the starters separately, we see that the FD, TTFF, and DD values are highest for Spanish music, but there are no significant differences between the music of the four nations. Italian music shows the highest values for FC and DC, followed by German and Spanish, with no significant differences. For FFD, Hungarian music captured the most visual attention while Italian music the least.

For main courses, Spanish music captured the most visual attention for FD, TTFF, and DD while Italian music captured the most visual attention for FC and DC, although no significant difference was observed between the music of the four nations.

For desserts, Spanish music captured the most visual attention for all parameters except the FD value. For FD, German music captured the most visual attention, but there was no significant difference between the effects of Spanish and German music.

The effect of music on the visual parameters is present, however, it is not general over the courses. A general result is that Spanish music generated the highest visual attention while participants required less time when Hungarian music was played. As the participants were Hungarians and this effect could be because of their familiarity with the music.

3.3. Effect of foods

Spanish starters received the highest visual attention in terms of FD, FC, DD, and DC while Italian starters received the lowest mean value for TTFF (Table 4).

For main dishes, the Spanish main dish received the most visual attention for FD, FC, and DD while FFD and DC showed no significant difference between the four nations. However, the highest values were observed for the Hungarian main dish for FFD and the Italian main dish for DC. In the case of desserts, the FD, FC, and DD values showed that the Hungarian dessert received the most visual attention.

Table 4
Analysis of variance on the effect of the food types on the visual parameters for all dishes, appetizers, main courses and desserts.

		FD	FC	TTFF	FFD	DD	DC
Appetizer	Esp	1.113 b	4.340 c	0.771 a	0.214 ab	1.265 b	1.720 a
	Ita	0.558 a	2.292 a	1.066 b	0.249 b	0.600 a	1.354 a
	Ger	0.805 ab	3.469 bc	1.003 ab	0.217 ab	0.893 ab	1.592 a
	Hun	0.832 ab	2.745 ab	0.780 ab	0.189 a	0.891 ab	1.362 a
Main dish	Esp	**0.774 b**	**3.284 b**	0.847 a	0.228 a	**0.856 a**	1.445 a
	Ita	0.693 ab	3.172 ab	**0.928 a**	0.218 a	0.764 a	**1.604 a**
	Ger	0.565 ab	2.556 ab	0.774 a	0.228 a	0.600 a	1.463 a
	Hun	0.536 a	2.343 a	0.832 a	**0.256 a**	0.770 a	1.532 a
Dessert	Esp	0.694 ab	3.019 ab	0.909 b	0.241 a	0.762 ab	1.566 a
	Ita	0.508 a	2.431 a	1.171 c	0.327 b	0.605 a	1.314 a
	Ger	0.514 a	2.217 a	0.951 bc	0.217 a	0.554 a	1.304 a
	Hun	0.895 b	3.592 b	0.535 a	0.268 ab	0.990 b	1.592 a

FD: fixation duration, FC: fixation count, TTFF: time to first fixation, DD: dwell duration, DC: dwell count, letters indicate homogenous subgroups defined by Tukey HSD test.

Table 3
Analysis of variance on the effect of the music of different nations on the visual parameters for all dishes, appetizers, main courses and desserts.

Data		FD	FC	TTFF	FFD	DD	DC
All dishes	Esp_m	0.813b	3.157b	1.026b	0.259b	0.963b	1.562b
	Ita_m	0.708b	3.134 ab	0.855 ab	0.246 ab	0.780b	1.599b
	Ger_m	0.802b	2.947 ab	0.771a	0.236 ab	0.878b	1.512 ab
	Hun_m	0.516a	2.587a	0.859 ab	0.213a	0.585a	1.305a
Appetizer	Esp_m	0.946a	3.133 ab	1.028a	0.228 ab	1.047a	1.422 ab
	Ger_m	0.940a	3.220 ab	0.904a	0.222 ab	0.993a	1.520 ab
	Ita_m	0.842a	3.981b	0.772a	0.178a	0.954a	1.827b
	Hun_m	0.588a	2.489a	0.934a	0.246b	0.666a	1.234a
Main course	Esp_m	0.761b	3.034a	1.012b	0.225 ab	0.960b	1.610a
	Ita_m	0.694b	3.057a	0.760 ab	0.271b	0.742 ab	1.623a
	Ger_m	0.640 ab	2.600a	0.682a	0.248 ab	0.789 ab	1.542a
	Hun_m	0.489a	2.586a	0.862 ab	0.202a	0.549a	1.329a
Dessert	Esp_m	0.752b	3.327b	1.042b	0.329c	0.890c	1.633a
	Ger_m	0.797b	2.958 ab	0.708a	0.242 ab	0.834bc	1.479a
	Ita_m	0.590 ab	2.365a	1.033b	0.288bc	0.646 ab	1.346a
	Hun_m	0.488a	2.680 ab	0.782a	0.198a	0.559a	1.340a

FD: fixation duration, FC: fixation count, TTFF: time to first fixation, DD: dwell duration, DC: dwell count, letters indicate homogenous subgroups defined by Tukey HSD test.

3.4. Relationship between choices and music

When it comes to choices, the relation between the meals and music of the nations can be examined. Fig. 3 shows the frequency of choice as a function of music. The figure clearly shows that the four nations can be divided into two groups, *i.e.* it can be seen that similar cultures, such as Hungarian-German and Spanish-Italian, are clearly separated from the other two nations both in terms of music and frequency of choice. When Hungarian or German music was played, participants tended to choose Hungarian or German dishes. The same stands for Spanish and Italian food choices and music.

The initial hypothesis was that there are significant differences between all four music and food groups, which was supported by Fig. 4 at first. However, when we merged the data of similar cultures, the results became even more expressed. Therefore, Hungarian-German food and music and Italian-Spanish food and music have been treated together (Table 5). The choice options for the starters show that music had no particular effect on food choice with more people choosing Italian-Spanish food (ItEsFood) over Hungarian-German music (HuGerMusic) and vice versa. For main courses and desserts, the effect of the music is already visible, as more people chose Hungarian-German dishes (HuGerFood) to the effect of Hungarian-German music (HuGerMusic) and vice versa. And if we look at the overall choices, this trend also holds.

3.5. Prediction of choice

As it has been earlier demonstrated (Gere et al., 2016, 2021) that choices can be successfully predicted using classification models based on eye-tracking data, in order to get a deeper understanding of the effect of ethnic music on meal choices, different classification models were run on the data sets with or without the sound condition. The classification performances of five models (LDA, linear discriminant analysis; ANN, artificial neural network; RF, random forest; SVM, support vector machine; KNN, *k*-nearest neighbour classifier) and eleven performance metrics (see Materials and methods section) were evaluated using the sum of ranking differences method (SRD). Although SRD gives a clear rank of the models, its proper validation based on (Héberger and Kollár-Hunek, 2019) has been completed. The results of the validation were evaluated by a factorial analysis of variance (ANOVA) (Table 6). The validation variants (F1 and F2) are not significant, only the constant term (intercept) and the factor classifier are. It means that regardless of their alternatives, the resampling approaches do not introduce any artifacts. The bias and variance of the k-fold CV are shown in Fig. S1.

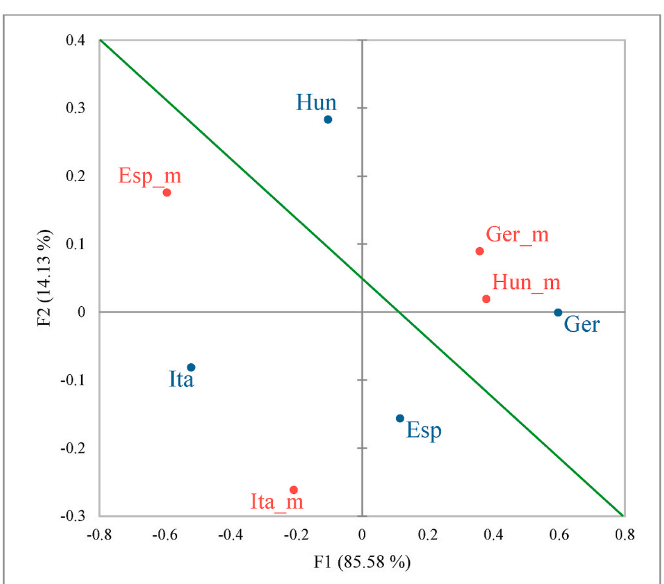

Fig. 3. Correspondence analysis BiPlot showing the frequency of choice as a function of music. Lowercase "m" denotes music. The straight green line is drawn arbitrary. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

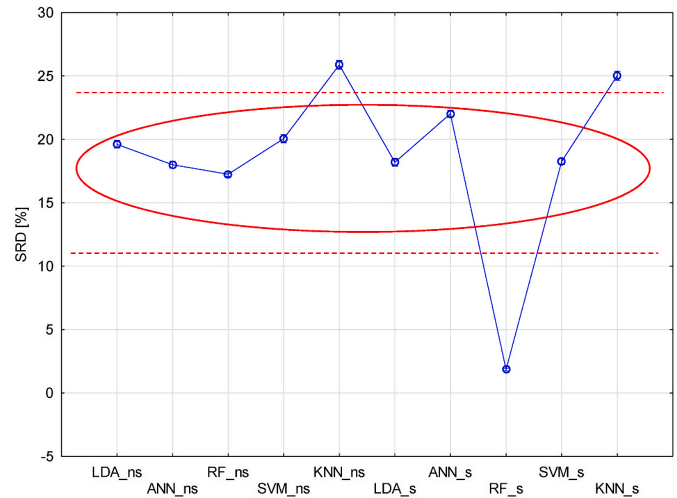

Fig. 4. Categorization of classifiers (the best ones have the smallest bias and smallest variance alike). The dotted lines represent visually set thresholds. Letters after the abbreviations denote models trained on eye-tracking data with (s) or without (ns) sound. LDA, linear discriminant analysi; ANN, artificial neural network; RF, random forest; SVM, support vector machine; KNN, *k*-nearest neighbour classifier, SRD, sum of ranking differences.

Table 5
The merged choice counts for all three courses and overall.

		HuGerMusic	ItEsMusic
Appetizer	HuGerFood	11	12
	ItEsFood	18	16
Main	HuGerFood	18	7
	ItEsFood	13	24
Dessert	HuGerFood	22	8
	ItEsFood	6	16
All	HuGerFood	51	27
	ItEsFood	37	56

Table 6
Decomposition of validation variants and performance of classifiers, i.e., univariate tests of significance for sum of ranking differences (SRD) (%)[a].

Intercept	df	SS	MS	*F*	*p*
	1	373,212.6	373,212.6	114,144.6	0.000000
F1: Contiguous/ resampling	2	1.2	0.6	0.2	0.831829
F2: Fivefold, sevenfold, and tenfold CV	1	2.0	2.0	0.6	0.432156
F3: Classifier	**9**	**42,254.1**	**4694.9**	**1435.9**	**0.000000**
F1*F2	9	4.1	0.5	0.1	0.998535
F1*F3	2	1.4	0.7	0.2	0.811720
F2*F3	18	3.1	0.2	0.1	1.000000
F1*F2*F3	18	1.4	0.1	0.0	1.000000
Error	1530	5002.6	3.3		

Abbreviations: CV, cross-validation; F, Fisher's criterion; MS, mean square residuals; df, degree of freedom; *p*, probability of significance; SS, sum of squared residuals. Significant items are indicated by bold.

[a] Sigma-restricted parameterization. Factors: F1—way of cross-validation (validation variants), two levels: contiguous and resampling. F2—number of folds, three levels: fivefold, sevenfold, and tenfold cross-validation. F3—classifiers to be compared, 28 levels.

However, factor 3 clearly distinguishes the biases, making it easy to classify the classifiers (Fig. 4). Here, as might be expected, the variances are not homogeneous. The classifiers can be divided into three classes simply (visually).

The analysis of interaction terms (coupling) is made possible using ANOVA. When one looks at Fig. S2, a very distinct pattern becomes apparent. With more folds, the variance reduces, but only when stratified contiguous sampling is used. This pattern is changed by frequent resampling. This proves that the initial data sets weren not manipulated in a random manner. The displayed data structure is clear.

Classifiers with SRD values between 18 and 21 belong to the medium group while the weakest ones have SRD values above 25. The kNN is not recommended as a classifier, with sound and non-sound (kNN_c, kNN_m) data showing values above 25. Fig. 4 shows that the best classifier is RF_m, despite the fact that RF_c is a medium classifier. Comparing the same models run on data sets with (m) or without music (c), it is clear that those running on the sound data show better performance.

4. Discussion

Hearing a particular style of music prior to eating influences food selections (Zellner et al., 2017). People tend to choose a meal that is congruent with the ethnic background music being played (Peng-Li et al., 2020). Our findings are in line with previous studies and confirm the effects of ethnic background music on the frequency of food choices. Furthermore, the results show that Hungarian-German and Spanish-Italian are differentiated from other nations both in terms of background music and frequency of food choice. Furthermore, we investigated the impact of ethnic background music on choices of starters, main dishes, and desserts from Germany, Hungary, Spain, and Italy. To the best of our knowledge, the association between four ethnic music and food including starters, main courses, and desserts has not been investigated before.

The geographically close countries' music should be treated together. Hungarian-German food and music, as well as Italian-Spanish food and music, are treated together by Hungarian participants. Correspondingly, French and German music was associated with British consumers. Playing French (German) music in a British supermarket's wine section significantly enhanced the selection of French (German) wine (North et al., 1997). Besides, previous research shows that country-specific music influences meal choices in that culture. A significantly greater proportion of paella (Spanish seafood) over chicken parmesan (Italian food) was selected by consumers in a University (USA) dining hall when Spanish music was played as compared to Italian music (Zellner et al., 2017). Peng-Li and co-workers found that both Chinese and Danish participants chose significantly more Eastern (vs. Western) food in the Eastern music condition and Western (vs. Eastern) food when Western music was played (Peng-Li et al., 2020).

Furthermore, the study shows that music has priming effects (Yeoh and North, 2010). Consumers' perception and decision-making process is the totality of environmental evaluation. Therefore, background music, individuals' preferences, and the theme of the dining environment have joint impacts on the food selection process. However, whether the perceived ethnic environment will significantly influence food selection remains unclear. We can only confirm that background music can influence food selection, but other factors need to be explored further. On one hand, Bell et al. (1994) conducted a British study and found when a restaurant was decorated with an Italian theme, the selection of Italian pasta and dessert items was increased and the selection of fish was decreased. On the other hand, while the quality of the environment might have an effect on liking, it is possible that the congruency of the environmental stimuli (*e.g.,* music) with food has no effect on liking (Zellner et al., 2017).

Although ethnic background music has a significant impact on the food selection process, due to variations in experimental conditions (text stimuli, audio stimuli, real dining environment, and VR lab), sample size, and music genres, the conclusions of the existing literature are controversial. For example, there is a contradiction in the function of background music in promoting the consumption of healthy foods (low-sugar, low-calorie foods). On one hand, the higher-pitched sounds (vs. lower-pitched sounds) promote the consumption of healthy foods (Motoki et al., 2022). On the other hand, high-volume music increases excitement levels, which tends to promote the consumption of unhealthy food (Biswas et al., 2019). Our findings also demonstrate that the cultural characteristics of music influence consumers' choice of meals with relevant cultural attributes.

This study has limitations in that, firstly, the background music was not defined by genre, tempo, and pitch. Studies have shown that the genre of music can significantly affect participants' meal selection when they don't have strong preferences. Ethnic music usually possesses a distinct tempo and pitch. Even though in neighboring countries, their ethnic music may hold significant variance in music psychology. The variations need to be further emphasized. Secondly, in selecting the type of stimuli, the current study employs picture stimuli. The more realistic environment is to a real dining scenario, the more information we might observe. Motoki et al. (2022) used text descriptions as opposed to visual or actual meals. However, neither text descriptions nor visual stimuli (image and video) are distinct from the dining environment, which generates abundant sensory experience and arouses cognitive processes. Therefore, further research on the actual dining environment is needed. In addition, the function or effects soundtrack is perhaps limited in terms of food selection. Future research needs to further examine the circumstances that make the effect of background music on food choices ineffective.

5. Conclusions

The decreased visual attention in the music condition reflects that music helped participants complete their choices faster and increased the cognitive process. This has also been supported by the prediction models, which showed increased prediction accuracy when music was played. There is a clear influencing effect of ethnic music on eye movements and congruent food choices, however, the four nations could not be differentiated clearly. Similar cultures (*e.g.* German-Hungarian and Italian-Spanish) showed no differences. However, when merging similar cultures, a clear differentiation was found. Geographically close countries' music usually should be treated together when consumers make a decision about food selection such as German-Hungarian and Italian-Spanish.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

CRediT authorship contribution statement

Dorina Szakál: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Visualization. **Xu Cao:** Data curation, Writing – original draft, Methodology. **Orsolya Fehér:** Writing – original draft, Writing – review & editing, Supervision, Project administration. **Attila Gere:** Conceptualization, Methodology, Investigation, Writing – review & editing, Supervision, Project administration, Funding acquisition.

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

The authors do not have permission to share data.

Acknowledgments

DSz thanks the support of the Doctoral School of Economic and Regional Sciences, Hungarian University of Agriculture and Life Sciences. XC thanks the support of the Doctoral School of Food Sciences, Hungarian University of Agriculture and Life Sciences. AG thanks the support of the János Bolyai Research Scholarship of the Hungarian Academy of Sciences. The authors thank the support of the National Research, Development, and Innovation Office of Hungary (OTKA, contracts No FK 137577 and K 134260).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.crfs.2023.100508.

References

Aheadi, A., Dixon, P., Glover, S., 2010. A limiting feature of the Mozart effect: listening enhances mental rotation abilities in non-musicians but not musicians. Psychol. Music 38 (1), 107–117. https://doi.org/10.1177/0305735609336057.

Alley, T.R., Greene, M.E., 2008. The relative and perceived impact of irrelevant speech, vocal music and non-vocal music on working memory. Curr. Psychol. 27 (4), 277–289. https://doi.org/10.1007/s12144-008-9040-z.

Anwar, A., Waqas, A., Zain, H.M., Kee, D.M.H., 2020. Impact of music and colour on customers' emotional states: an experimental study of online store. Asian J. Bus. Res. 10 (1), 104–125. https://doi.org/10.14707/ajbr.200077.

Avila, C., Furnham, A., McClelland, A., 2012. The influence of distracting familiar vocal music on cognitive performance of introverts and extraverts. Psychol. Music 40 (1), 84–93. https://doi.org/10.1177/0305735611422672.

Beanland, V., Allen, R.A., Pammer, K., 2011. Attending to music decreases inattentional blindness. Conscious. Cognit. 20 (4), 1282–1292. https://doi.org/10.1016/j.concog.2011.04.009.

Bell, R., Meiselman, H.L., Pierson, B.J., Reeve, W.G., 1994. Effects of adding an Italian theme to a restaurant on the perceived ethnicity, acceptability, and selection of foods. Appetite 22 (Issue 1), 11–24. https://doi.org/10.1006/appe.1994.1002.

Biswas, D., Lund, K., Szocs, C., 2019. Sounds like a healthy retail atmospheric strategy: effects of ambient music and background noise on food sales. J. Acad. Market. Sci. 47 (1), 37–55. https://doi.org/10.1007/s11747-018-0583-8.

Braunstein, L.M., Gross, J.J., Ochsner, K.N., 2017. Explicit and implicit emotion regulation: a multi-level framework. Soc. Cognit. Affect Neurosci. 12 (10), 1545–1557. https://doi.org/10.1093/scan/nsx096.

Bytyçi, S., 2020. Influence of colors as a key element in consumer marketing. Exper. J. Market 8 (1), 41–47.

Cassidy, G., Macdonald, R.A.R., 2007. The effect of background music and background noise on the task performance of introverts and extraverts. Psychol. Music 35 (3), 517–537. https://doi.org/10.1177/0305735607076444.

Cho, C.H., Mattila, A., Bordi, P., Kwon, E., 2020. It tastes better when Bach meets red: the role of music and plate color on food evaluation. Br. Food J. 122 (1), 14–25. https://doi.org/10.1108/BFJ-02-2018-0100.

Cui, T., Xi, J., Tang, C., Song, J., He, J., Brytek-Matera, A., 2021. The relationship between music and food intake: a systematic review and meta-analysis. Nutrients 13 (8), 1–12. https://doi.org/10.3390/nu13082571.

Damen, M., Van Hest, I., Wernaart, B., 2021. The effect of stereotypical music on the customer selection of wine in an online environment. J.Innova. Digi Market. 2 (2), 29–37. https://doi.org/10.51300/jidm-2021-35.

De Groot, A.M.B., 2006. Effects of stimulus characteristics and background music on foreign language vocabulary learning and forgetting. Lang. Learn. 56 (3), 463–506. https://doi.org/10.1111/j.1467-9922.2006.00374.x.

De Luca, M., Campo, R., Lee, R., 2019. Mozart or pop music? Effects of background music on wine consumers. Int. J. Wine Bus. Res. 31 (3), 406–418. https://doi.org/10.1108/IJWBR-01-2018-0001.

Errajaa, K., Daucé, B., Legohérel, P., 2020. Consumer reactions to olfactory congruence with brand image. J. Retailing Consum. Serv. 52, 101898 https://doi.org/10.1016/j.jretconser.2019.101898. July 2019.

Fiedler, S., Schulte-Mecklenbeck, M., Renkewitz, F., Orquin, J.L., 2020. Guideline for Reporting Standards of Eye-Tracking Research in Decision Sciences. PsyArXiv.

Gere, A., Danner, L., de Antoni, N., Kovács, S., Dürrschmid, K., Sipos, L., 2016. Visual attention accompanying food decision process: an alternative approach to choose the best models. Food Qual. Prefer. 51, 1–7. https://doi.org/10.1016/j.foodqual.2016.01.009.

Gere, A., Héberger, K., Kovács, S., 2021. How to predict choice using eye-movements data? Food Res. Int. 143, 110309 https://doi.org/10.1016/j.foodres.2021.110309.

Golnar-Nik, P., Farashi, S., Safari, M.S., 2019. The application of EEG power for the prediction and interpretation of consumer decision-making: a neuromarketing study. Physiol. Behav. 207, 90–98. https://doi.org/10.1016/j.physbeh.2019.04.025. August 2018.

Hammerschmidt, D., Wollner, C., 2018. The impact of music and stretched time on pupillary responses and eye movements in slow-motion film scenes. J. Eye Move. Res. 11 (2), 1–17. https://doi.org/10.16910/jemr.11.2.10.

Héberger, K., 2010. Sum of ranking differences compares methods or models fairly. TrAC, Trends Anal. Chem. 29 (1), 101–109. https://doi.org/10.1016/j.trac.2009.09.009.

Héberger, K., Kollár-Hunek, K., 2011. Sum of ranking differences for method discrimination and its validation: comparison of ranks with random numbers. J. Chemometr. 25 (4), 151–158. https://doi.org/10.1002/cem.1320.

Héberger, K., Kollár-Hunek, K., 2019. Comparison of validation variants by sum of ranking differences and ANOVA. J. Chemometr. 33 (6), e3104 https://doi.org/10.1002/cem.3104.

Huang, X., Labroo, A.A., 2020. Cueing morality: the effect of high-pitched music on healthy choice. J. Market. 84 (6), 130–143. https://doi.org/10.1177/0022242918813577.

Jeong, S., Lee, J., 2021. Effects of cultural background on consumer perception and acceptability of foods and drinks: a review of latest cross-cultural studies. Curr. Opin. Food Sci. 42, 248–256. https://doi.org/10.1016/j.cofs.2021.07.004.

Kim, K., Zauberman, G., 2019. The effect of music tempo on consumer impatience in intertemporal decisions. Eur. J. Market. 53 (3), 504–523. https://doi.org/10.1108/EJM-10-2017-0696.

Krishna, A., 2012. An integrative review of sensory marketing: engaging the senses to affect perception, judgment and behavior. J. Consum. Psychol. 22 (3), 332–351. https://doi.org/10.1016/j.jcps.2011.08.003.

Li, L., 2017. The study on human-computer interaction design based on the users' subconscious behavior. IOP Conf. Ser. Mater. Sci. Eng. 242 (1) https://doi.org/10.1088/1757–899X/242/1/012125.

Lwin, M.O., Morrin, M., Chong, C.S.T., Goh, S.X., 2016. Odor semantics and visual cues: what we smell impacts where we look, what we remember, and what we want to buy. J. Behav. Decis. Making 29 (2–3), 336–350. https://doi.org/10.1002/bdm.1905.

Motoki, K., Takahashi, N., Velasco, C., Spence, C., 2022. Is classical music sweeter than jazz? Crossmodal influences of background music and taste/flavour on healthy and indulgent food preferences. Food Qual. Prefer. 96 (June 2021), 104380 https://doi.org/10.1016/j.foodqual.2021.104380.

North, A.C., Hargreaves, D.J., McKendrick, J.M., 1997. In-store music affects product choice [10]. Nature 390 (6656), 132. https://doi.org/10.1038/36484.

Olivers, C.N.L., Nieuwenhuis, S., 2005. The beneficial effect of concurrent task-irrelevant mental activity on temporal attention. Psychol. Sci. 16 (4), 265–269. https://doi.org/10.1111/j.0956-7976.2005.01526.x.

Orquin, J.L., Mueller Loose, S., 2013. Attention and choice: a review on eye movements in decision making. Acta Psychol. 144 (1), 190–206. https://doi.org/10.1016/j.actpsy.2013.06.003.

Pantoja, F., Borges, A., 2021. Background music tempo effects on food evaluations and purchase intentions. J. Retailing Consum. Serv. 63 (November 2020), 102730 https://doi.org/10.1016/j.jretconser.2021.102730.

Patston, L.L.M., Toppett, L.J., 2011. The effect of background music on cognitive performance in musicians and nonmusicians. Music Perception 13 (3), 173–183. https://doi.org/10.1525/mp.2011.29.2.173.

Paulo, F.J de, Simiqueli, A.A., Tabel, C.J., Crepalde, L.T., Minim, L.A., Minim, V.P.R., 2022. The Effect of Background Music on Sensory Evaluation of Craft Beer. Research, Society and Development, pp. 1–12. https://doi.org/10.33448/rsd-v11i9.31620, 2022.

Peng-Li, D., Alves Da Mota, P., Correa, C.M.C., Chan, R.C.K., Byrne, D.V., Wang, Q.J., 2022. Sound" decisions: the combined role of ambient noise and cognitive regulation on the neurophysiology of food cravings. Front. Neurosci. 16 (February), 1–16. https://doi.org/10.3389/fnins.2022.827021.

Peng-Li, D., Byrne, D.V., Chan, R.C.K., Wang, Q.J., 2020a. The influence of taste-congruent soundtracks on visual attention and food choice: a cross-cultural eye-tracking study in Chinese and Danish consumers. Food Qual. Prefer. 85 (May), 103962 https://doi.org/10.1016/j.foodqual.2020.103962.

Peng-Li, D., Chan, R.C.K., Byrne, D.V., Wang, Q.J., 2020b. The effects of ethnically congruent music on eye movements and food choice-a cross-cultural comparison between Danish and Chinese consumers. Foods 9 (8). https://doi.org/10.3390/foods9081109.

Peng-Li, D., Mathiesen, S.L., Chan, R.C.K., Byrne, D.V., Wang, Q.J., 2021. Sounds Healthy: modelling sound-evoked consumer food choice through visual attention. Appetite 164 (October 2020), 105264. https://doi.org/10.1016/j.appet.2021.105264.

R Core Team, 2023. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. URL. https://www.R-project.org/.

Reinoso Carvalho, F., Wang, Q.J., Van Ee, R., Spence, C., 2016. The influence of soundscapes on the perception and evaluation of beers. Food Qual. Prefer. 52, 32–41. https://doi.org/10.1016/j.foodqual.2016.03.009.

Sassenberg, A.-M., Sassenberg, C., Sassenberg, C., Heneghan, M., 2022. Effects of atmosphere on emotions and consumer behaviour at wineries. Int. J. Wine Bus. Res. 34 (4), 523–541. https://doi.org/10.1108/IJWBR-05-2021-0028.

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

Szakál, D., Fehér, O., Radványi, D., Gere, A., 2022. Effect of scents on gazing behavior and choice. Appl. Sci. 16, 6899. https://doi.org/10.3390/app12146899 Academic.

Zellner, D., Geller, T., Lyons, S., Pyper, A., Riaz, K., 2017. Ethnic congruence of music and food affects food selection but not liking. Food Qual. Prefer. 56, 126–129. https://doi.org/10.1016/j.foodqual.2016.10.004.