Food Quality and Preference 99 (2022) 104544

Contents lists available at ScienceDirect

Food Quality and Preference

journal homepage: www.elsevier.com/locate/foodqual

Short Communication

That sounds healthy! Audio and visual frequency differences in brand sound logos modify the perception of food healthfulness

Monin Techawachirakul [a,b,*], Abhishek Pathak [c], Gemma Anne Calvert [a]

[a] Nanyang Business School, Nanyang Technological University, Singapore
[b] Department of Psychology, Thammasat University, Thailand
[c] School of Business, University of Dundee, UK

ARTICLE INFO

Keywords:
Crossmodal correspondence
Sonic logos
Food healthfulness
Frequency
Tempo
Sensory branding

ABSTRACT

Sonic brand logos, also termed “sogos”, are a marketing communication tool that brands use to signify brand or product benefits to consumers in catchy, non-visual ways. Given the considerable utility of brand lsogos, it is surprising that there has been scant research into the nature of the specific acoustic features that can be modulated to connote certain traits, such as the healthfulness of products within the food category. Our findings revealed that sogos created with higher (vs. lower) frequency were significantly matched with healthy food products (vs. less healthy), while the effect of tempo was neutral. This effect generalizes to high (vs. low) spatial frequency visual stimuli too. The current study contributes to the literature on the crossmodal correspondence between acoustic sound clips and expectations of healthfulness. It also advances the theoretical insights into business applications using optimal sogos congruent with visual cues on packaging to connote food healthfulness to consumers implicitly.

1. Introduction

Sensory stimuli (e.g., sounds, colours) play a prominent role in branding. A sonic logo (also termed a sogo) is an integral part of branding and is comprised of a short melody created to support the marketing of a specific brand with the unique selling proposition that the brand offers e.g., McDonald’s “I’m loving it” sogo which is crafted in a major key such that it sounds pleasing and playful (Bonde & Hansen, 2013). Compared to other audio assets, sogos tend to be more flexible and adjustable as they can be used across a variety of physical and digital touchpoints to help connect brands to customers at a deep, implicit level in a less cluttered (non-visual) sensory domain (Bonde & Hansen, 2013; Goyal, 2019). These unique properties distinguish sogos from other audible marketing tools, such as background music played in-store or TV advertisements which are not designed necessarily to convey brand identity. Brands thus invest time and financial resources to create these distinctive sound signatures which become a part of their brand identity (e.g., Windows’s start-up chime) and consumers quickly learn to associate these short clips with the brands they represent (Goyal, 2019). Importantly, brand managers and agencies need to ensure that sogos are perceived as congruent with the brand and/or product they represent. Recent research suggests that when music is congruent with the associated food/beverage attributes (e.g., ‘sweet music’ played with the presentation of a sweet meal), participants fixate their eyes on the meal longer, reflecting higher attention, than incongruent combinations (Peng-Li, Byrne, Chan, & Wang, 2020). Congruency between product category and the sound of a brand name can also influence positive responses towards food products (e.g., taste expectations and purchase intention) (Fenko, Lotterman, & Galetzka, 2016; Lee & Labroo, 2004; Reber, Schwarz, & Winkielman, 2004). Congruent stimuli enhance the ease of processing, which in turn leads to a more pleasant experience. Thus, achieving this sense of perceptual congruence is important in the context of sogos.

The growth of consumer interest in healthier food choices has urged brands to strive for strategies by which to communicate food healthfulness in competitive markets. While past research on acoustic influences on consumer decision making has mostly focused on how ambient music and background noise influences choice behavior (including the selection of healthy items), similar research on sogos is sparse (e.g., Biswas, Lund, & Szocs, 2019; Mathiesen, Mielby, Byrne, & Wang, 2020). For example, sogos for junk foods would inevitably sound different from sogos for healthy alternatives. Within the food category, creatively crafted sogos have been used to connote food flavours (e.g., vanilla and citrus) (Bronner, Frieler, Bruhn, & Hirt, 2012), to enhance

* Corresponding author at: Division of Marketing, Nanyang Business School, 50 Nanyang Avenue, 639798, Singapore.
E-mail address: Monin001@e.ntu.edu.sg (M. Techawachirakul).

https://doi.org/10.1016/j.foodqual.2022.104544
Received 7 November 2021; Received in revised form 22 January 2022; Accepted 25 January 2022
Available online 3 February 2022
0950-3293/

brand recognition (Bonde & Hansen, 2013), and to influence willingness-to-buy of the associated product (Krishnan, Kellaris, & Aurand, 2012). Given the considerable utility of brand sogos, it is surprising that to date there has been scant research into the nature of the specific acoustic musical features that can be modulated to connote certain traits (e.g., healthfulness). While previous studies have demonstrated that music can influence consumer decision making processes towards healthy foods through underlying mechanisms of morality cues (Huang & Labroo, 2019), music-evoked emotions or arousal (Motoki, Takahashi, Velasco, & Spence, 2022), and visual attention (Peng-Li, Mathiesen, Chan, Byrne, & Wang, 2021), the current research enriches the literature by systematically evaluating the effect of frequency and tempo present in hypothetical brand sogos and the association with food healthfulness.

2. Theoretical background

2.1. Frequency

Frequency is the most critical aspect of sound that makes a commercial sogo unique as it is more discriminable than other musical features (Bonde & Hansen, 2013). In the last decade, the association between the frequency of a sound and the attributes of food products (e.g., taste, crispiness, freshness, harshness) has been investigated extensively (e.g., see Spence et al., 2019 for a review). For example, high (vs. low) frequency sounds have been reliably mapped with sweet (vs. bitter) tastes (e.g., Reinoso Carvalho et al., 2016) and crispiness (Zampini & Spence, 2004). Similarly, alcoholic beverages bearing names with high (vs. low) frequency sounds are perceived as harsh (vs. mild) (Pathak, Calvert, & Lim, 2020).

Relevant to the current paper, high (vs. low) frequency sounds present in linguistic stimuli (e.g., brand names) are perceived as healthy (vs. unhealthy) (Motoki, Park, Pathak, & Spence, 2021). Similarly, high (vs. low) frequency sounds have been shown to be linked with small and light objects (Walker, 2016) and healthy (vs. unhealthy) foods are linked with small and light portions (Motoki et al., 2021). Background sounds (e.g., music and ambient sounds) can also influence eating behaviour, such that high (vs. low) frequency sounds often lead consumers to select small (vs. bigger) portion sizes (Lowe & Haws, 2017; Lowe, Ringler, & Haws, 2018). It has also been shown that consumers make healthier (vs. unhealthy) food choices when ambient sounds are played in high (vs. low) frequency (Huang & Labroo, 2019). Another study has identified that high (vs. low) frequency is one of the important determinants in creating a healthy (vs. unhealthy) soundtrack (Peng-Li et al., 2021). This appears to be consistent with a recent study revealing that music genre (e.g., classic and jazz) containing high frequency components induces consumers to prefer healthy foods in contrast to rock/metal genres (Motoki et al., 2022). Given this evidence, we predicted that sogos with high (vs. low) frequency sounds would be expected to be more associated with healthier (vs. less healthy) food.

2.2. Tempo

While the existing literature has mostly emphasized the effect of frequency on consumer expectations, this paper also investigates the effect of tempo, which is another important musical component that can influence food perception (Bronner et al., 2012; Knoferle & Spence, 2012). While there has been no documented report studying solely the effect of tempo on expectations of food healthfulness, recent research has demonstrated that classical and jazz music containing slow tempo affects selection and preference of healthy foods (Motoki et al., 2022; Peng-Li et al., 2021). Peng-Li et al. (2021) used a combination of auditory features to compose complex soundtracks including 'healthy' (e.g., jazz piece, slow tempo, and high-pitched piano) and 'unhealthy' (e.g., fast tempo, low-pitched, and dissonant guitar) soundtracks which are associated with healthy and unhealthy eating respectively. The results showed that the healthy soundtrack influenced participants' selection of healthy (vs. unhealthy) food choices relative to the unhealthy soundtrack. In a similar vein, Motoki and colleagues (2022) had participants listen to music with different music genres and indicated their intention to eat different foods comprised of healthy savoury, healthy sweet, unhealthy savoury, and unhealthy sweet foods. The results showed that classical music, which was predominantly linked with slow tempo pieces, led to an increase in preferences for both healthy savoury and healthy sweet foods compared to rock/metal and hip-hop music. Hence, we predicted that sogos with slow (vs. fast) tempo would be expected to be more closely associated with healthier (vs. less healthy) foods.

3. Sogo development

The sogos used in this study were created and manipulated using the Audacity software (https://www.audacityteam.org/). The sogos comprised of novel short melodies without the inclusion of a human voice to rule out the confounding effect of spoken words. The melodies for the sogos were generated using the Random Music Generator online software (https://random-music-generators.herokuapp.com/melody) and comprised of major notes ranging from C4 to B4 (261.63–493.88 Hz), moderate tempo (95 beats per minute (bpm)), and a constant rhythm at the eighth note (1/2 beat). The frequency and tempo of each melody was then manipulated. The frequency of melody was shifted by an octave (12 semitones) to create four melodies differing in the frequency range: very low frequency (65.41–123.47 Hz), low frequency (130.81–146.94 Hz), moderate frequency (261.63–493.88 Hz), and high frequency (523.25 – 987.77 Hz). For the tempo manipulation, the tempo of the melody was adjusted to slow tempo (70 bpm), moderate tempo (95 bpm), and fast tempo (145 bpm) (MasterClass, 2020). Once the sogos were created, they were adjusted to be approximately 9 s in length with normalized loudness at −20 dB RMS (a sample of sogos is available at https://soundcloud.com/musicclipss/10-c4tob4-95bpm?si=efc3093eee83449399e7cd575625965c).

A pretest was conducted to ensure that the pleasantness of tunes used as sogos[1] in the main studies was controlled. 56 participants (31 males and 25 females) between the ages of 24 to 69 years ($M = 38.46$ years, $SD = 11.61$) were recruited. Using G*Power 3.1.9 (Faul, Erdfelder, Lang, & Buchner, 2007), the sample size had 95% power to detect a medium-sized effect (0.25) in the repeated measures ANOVA. Participants took part in a 4 (frequency: very low, low, moderate, and high) × 3 (tempo: slow, moderate, vs. fast) within-participants pre-test where they rated the pleasantness of sogos on an 11-point Likert scale (from 1 = not pleasing at all to 11 = extremely pleasing). Participants also reported their proficiency in musical training (from 1 = not at all trained to 11 = very well trained), and musical knowledge (from 1 = not at all good to 11 = very good).

Participants rated sogos with very low and moderate frequencies to be significantly different in terms of their pleasantness appeal and thereby these logos were discarded. No difference was found in the pleasantness appeal of sogos created in low and high frequencies and low and fast tempos (frequency: $F(1,55) = 1.78$, $p = .19$; tempo: $F(1,55) = 0.30$, $p = .60$), thereby these logos were retained for the subsequent studies. No effect of the level of musical training nor of the musical knowledge was noted.

4. Method and overview of studies

Participants were presented with hypothetical sogos (Study 1 and 2) or visual cues (Study 3) followed by images of food products and then asked to select the food that they felt best matched the sogo. Each sogo was automatically played one at a time. All studies were programmed on

[1] Sogos are referred to tunes (series of musical notes) in this study, the terms 'tunes' and 'sogos' will be used interchangeably.

the Qualtrics online survey platform (https://www.qualtrics.com). Participants were native English speakers residing in the USA and recruited from Amazon Mechanical Turk. They were invited to take part in only one of the studies in the present research and were compensated for their time and effort. They were first asked to provide consent and demographical information and then took part in a few practice trials before proceeding to the main task. Using G*Power 3.1.9 (Faul et al., 2007), the sample size (n ≈ 60 for all studies) had 95% power to detect a medium-sized effect (0.5) in the Wilcoxon signed-rank test. The research was approved by the ethics committee of a large northern university in the UK.

5. Study 1

5.1. Participants

Sixty participants (39 males and 21 females) between the ages of 22 and 63 years ($M = 36.67$ years, $SD = 8.96$) took part in the study.

5.2. Stimuli

Sogos selected in the pretest were used as the auditory stimuli. Visual stimuli were selected from the standardized food images of the CROCUFID database (Toet et al., 2019) and F4H Image Collection (Charbonnier, van Meer, van der Laan, Viergever, & Smeets, 2016) to control the colour tones within each food category. The images comprised of three healthy foods (green salad, fruit salad, and tomato and cucumber salad) and three unhealthy foods (cheeseburger, French fries, and chocolate cookies) (Bucher, Müller, & Siegrist, 2015; Plasek, Lakner, & Temesi, 2020) (see Appendix 1).

5.3. Design and procedure

A 2 (frequency: high vs. low) × 2 (tempo: slow vs. fast) within-participants design was conducted. Participants were informed that a food company has a range of new products and wanted to select sogos that can convey the healthfulness of its food products. They were instructed to listen to the sogos and then select the food that they felt best matched the sogo. Each sogo was paired with one healthy and unhealthy food image. The pairing of food images was randomized and the position (i.e., left vs. right) was counterbalanced within-participant. The experiment lasted for approximately 8 minutes. To rule out the role of familiarity, participants also rated the familiarity of sogos after the experiment (from 1 = not at all familiar to 11 = very familiar).

5.4. Results and discussion

Data were analysed using SPSS 22.0 for Windows (IBM SPSS Inc., Chicago, IL, USA). As the Shapiro-Wilk Normality test revealed that the null hypotheses of normal population distributions were rejected at $p < .05$, non-parametric statistical methods were used for subsequent data analysis.

For each individual feature of sogos (i.e., frequency and tempo), the Wilcoxon signed-rank test was performed to determine whether participants differ in matching food images with two feature levels. Specifically, the percentage of healthy food selection was compared between low vs. high frequency and slow vs. fast tempo. The results revealed that participants expected the sogos with high (vs. low) frequency to be more associated with healthy (vs. unhealthy) foods ($M_{high} = 73.89\%$[2], $SD = 27.16$, $M_{low} = 48.89\%$, $SD = 32.16$; $z = 3.64$, $p < .001$, $r = 0.33$), while they expected sogos with slow (vs. fast) tempo to be more associated with healthy (vs. unhealthy) foods at a marginally significant level ($M_{slow} = 66.11\%$, $SD = 25.85$, $M_{fast} = 56.67\%$, $SD = 27.82$; $z = 1.91$, $p = .056$, $r = 0.17$) (see Fig. 1). No effect of the familiarity of the sogos was found[3]. The findings imply that the sogos with high frequency and slow tempo were expected to be more associated with healthy foods (when compared to sogos created in low frequency and fast tempo which were more associated with unhealthy foods).

6. Study 2

While Study 1 provided evidence for an association of sogos with healthy vs. unhealthy categories of foods, it is plausible that the category of food (e.g., salad vs. burger) possibly influenced the results. We, therefore, wanted to extend these findings to a similar food category by varying the healthfulness appeal (e.g., by ingredients), such as soy burgers which are perceived as healthier than beef burgers (Motoki et al., 2021). Thus, Study 2 was conducted to test whether the association between sogos and healthfulness extends to foods *within* the same category (e.g., healthy burger vs. unhealthy burger or healthy vs. unhealthy salad). If this is the case, the significant association between high (vs. low) frequency and slow (vs. fast) tempo with healthy (vs. less healthy) foods should be observed. As the colour tones of the images used for foods in Study 1 might have affected the results, in Study 2, the colour tones of the images used were matched.

6.1. Participants

Fifty-nine participants (28 males and 31 females) between the ages of 20 to 68 years ($M = 41.17$ years, $SD = 11.37$) took part in the study.

6.2. Stimuli

Sogos selected in the pretest were used as the auditory stimuli. Visual stimuli (images of foods) were selected from freely available resources online. The images comprised of two variations of burger (soy burger vs. bacon burger) and two variations of salad bowl (spring salad vs. spring salad with fries). In all images, special care was taken to ascertain similar backgrounds, viewpoints, and colour tones to minimize any confounds. To create the unhealthy version of a salad, the image of fries were superimposed on the salad image (since fries are perceived as unhealthier; Bucher et al., 2015). All images were presented at a resolution of 300 × 300 px (see Appendix 2).

A pretest was conducted to verify the perceived healthfulness of the selected images. 58 participants (23 males, 33 females, and 2 with unspecified gender) between the ages of 26 to 70 years ($M = 44.33$ years, $SD = 12.15$) rated the images on perceived healthfulness on a visual analog scale (VAS) from 0 (not at all healthy) to 100 (very healthy). As expected, an independent samples *t*-test revealed that soy burger and spring salad were perceived as healthier than spring salad with fries and bacon burger (soy burger: $M = 62.17$, $SD = 22.80$; bacon burger: $M = 14.36$, $SD = 15.02$; $t(57) = 13.03$, $p < .001$, $d = 1.71$; spring salad: $M = 89.90$, $SD = 11.49$; spring salad with fries: $M = 41.64$, $SD = 25.90$; $t(57) = 14.04$, $p < .001$, $d = 1.84$).

6.3. Design and procedure

A 2 (frequency: high vs. low) × 2 (tempo: slow vs. fast) within-participants design (similar to Study 1) was used. Participants were presented with a pair of healthy and less healthy foods (e.g., soy burger vs. bacon burger, spring salad vs. spring salad with fries) and were asked to select the food that they felt best matched the sogo. Subsequently, the data were analysed as described above in Study 1.

[2] *M* is the averaged proportion of trials that participants selected in healthy over unhealthy food choices.

[3] Though the data was not normally distributed, a repeated measures ANOVA was used with familiarity as a covariate. No effect of familiarity was observed (frequency: $F(1,58) = 0.98$, $p = .33$; tempo: $F(1,58) = 0.15$, $p = .70$).

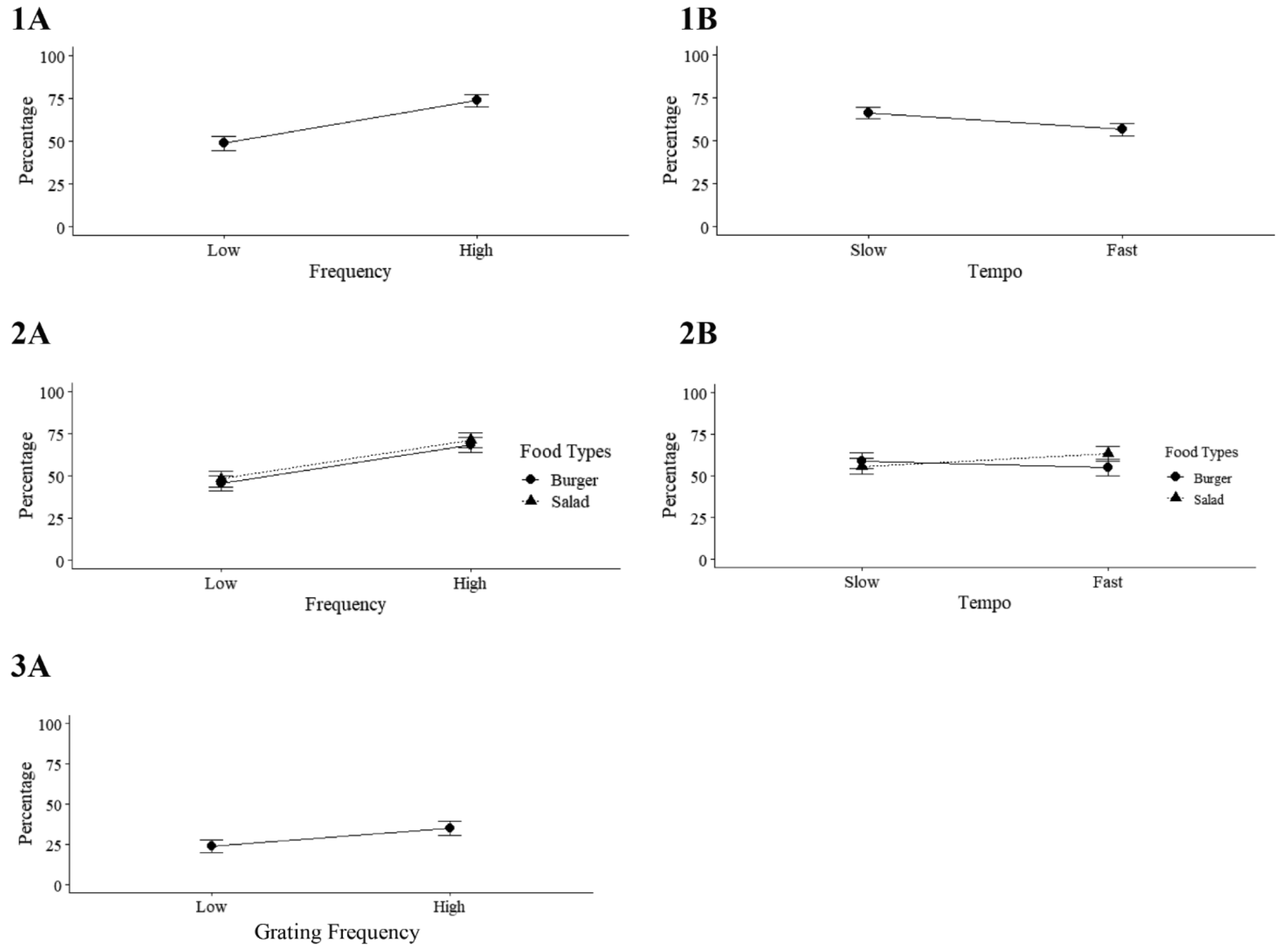


Fig. 1. Percentage of healthy food selection as a function of the frequency (1A, 2A, and 3A) and tempo (1B and 2B). The upper panel represents the responses towards sogos across food categories (Study 1). The middle panel represents the comparison of responses towards sogos within each food category (Study 2). The lower panel illustrates the responses towards grating images across food categories (Study 3). Error bars represent the standard error of the means.

6.4. Results and discussion

A Wilcoxon signed-rank test was performed to determine whether participants differ in matching food images with the types of sogos. Specifically, the percentage of healthier food selections was compared between sogos with low vs. high frequency and slow vs. fast tempo. The results revealed that participants expected the sogos with high (vs. low) frequency to be more associated with the healthy (vs. less healthy) foods ($M_{high} = 69.92\%$, $SD = 28.91$, $M_{low} = 47.03\%$, $SD = 31.17$; $z = 3.73$, $p < .001$, $r = 0.34$); no effect of the tempo nor of the type of food category was observed (tempo: $M_{slow} = 57.63\%$ $SD = 32.58$, $M_{fast} = 57.20\%$, SD $= 25.87$; $z = 0.03$, $p = .97$; type of food category (i.e., burger vs. salad): $F(1, 116) = 0.34$, $p = .56$[4]; burger: $M = 57.20\%$, $SD = 24.59$; salad: $M = 59.75\%$, $SD = 22.75$).

Data was also analyzed separately for both the categories of food (i.e., burger and salad), which revealed similar results. Participants expected the sogos with high (vs. low) frequency to be more associated with healthy (vs. less healthy) food (burger: *frequency*: $M_{high} = 68.64\%$, $SD = 34.61$, $M_{low} = 45.76\%$, $SD = 35.10$; $z = 3.17$, $p = .002$, $r = 0.29$; salad: *frequency*: $M_{high} = 71.19\%$, $SD = 33.74$, $M_{low} = 48.31\%$, $SD = 371.10$; $z = 2.93$, $p = .003$, $r = 0.27$); no effect of tempo was observed (burger: $M_{slow} = 59.32\%$, $SD = 35.32$, $M_{fast} = 55.08\%$, $SD = 37.94$; $z = 0.58$, $p = .57$; salad: $M_{slow} = 55.93\%$, $SD = 36.06$, $M_{fast} = 59.32\%$, $SD = 25.38$; $z = 0.85$, $p = .40$).

7. Study 3

In addition to acoustic frequency, in a follow-up study, we investigated whether the frequency effects observed in the acoustic domain would generalize to the visual modality (specifically, high versus low frequency visual stimuli as widely used in the psychophysics literature; Landy, 2006). These might provide insight in certain characteristics of striped pack designs (e.g., higher frequency gratings) and how they may connote healthfulness. By analogy, the graphical representations of sound waves are simple sinusoidal (sine) waveforms which represent the area of compression and rarefaction of air molecules while the sounds are transmitted. This resembles a visual image known as a sine wave grating (stripes of black and white) where the bands represent the low and high intensity of light and its frequency is measured in terms of the number of cycles per visual degree (higher cycles indicate higher spatial frequency: see Fig. 2). In line with the crossmodal effect, participants automatically map high (vs. low) frequency musical tones with high (vs. low) spatial frequency images (Evans & Treisman, 2010). Considering our findings on the correspondence between high frequency sogos and food healthfulness, we hypothesized that if the crossmodal association between high-frequency sounds and healthfulness holds true, this association should also be observed in the presence of high frequency images. We, therefore, used sine-wave grating images (visual) as proxies for the acoustic stimuli (used in Studies 1 and 2) and hypothesized that high (vs. low) spatial frequency grating images would be associated with

[4] Though the data was not normally distributed, a mixed repeated measures ANOVA was used to test the effect of the food category (burger vs. salad).

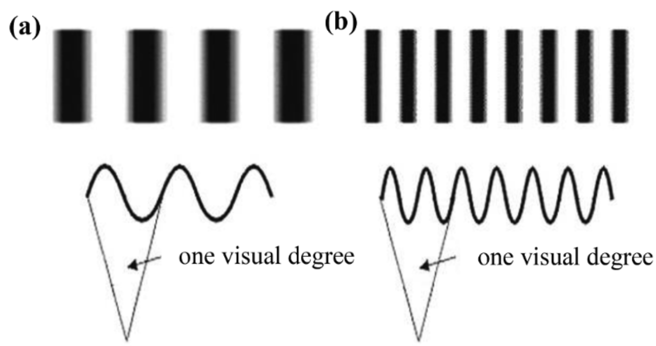


Fig. 2. Sine-wave gratings and measurement of frequency. The frequency of sine-wave gratings is measured in terms of the number of cycles per visual degree. (a) Low spatial frequency (one cycle per degree) (b) High spatial frequency (two cycles per degree) (Kalloniatis & Luu, 2007).
Source: http://webvision.med.utah.edu/

healthy (vs. unhealthy) foods.

7.1. Participants

Fify-eight participants (32 males and 26 females) between the ages of 23 to 77 years ($M = 44.10$ years, $SD = 13.76$) took part in the study. Data of one participant who spent over 10 minutes to complete the task was excluded.

7.2. Stimuli

The visual stimuli were black and white sine-wave gratings created using PsychoPy 2 (Peirce et al., 2019). The gratings had bars oriented at 0°, 45°, 90°, and 135°, moderate contrast of 1, and resolution of 280 × 280 px. The spatial frequencies were manipulated at high (12 cycles/degree) and low (4 cycles/degree) frequency (see Appendix 3). Food images comprised of healthy foods (salad, fruit salad, salad with shrimps, and tuna salad) and unhealthy foods (French fries, cheeseburger, brownies and donuts) and were selected from the F4H Image Collection (Charbonnier et al., 2016). Food images were presented at a resolution of 350 × 240 px and were randomly paired and counterbalanced (i.e., left vs. right position) for each participant.

A pre-test was conducted to verify the association of high (vs. low) frequency sogos and high (vs. low) frequency grating images. 60 participants (33 males, 26 females, and 1 with unspecified gender) between the ages of 23 and 75 years ($M = 41.53$ years, $SD = 12.95$) were instructed to select a grating image that they felt best matched the sogo. Data of two participants who spent over 10 minutes to complete the task were excluded. As predicted, an independent samples t-test revealed that high (vs. low) frequency sogos were associated with high (vs. low) frequency grating images ($M_{high\text{-}freq} = 75.86\%$[5], $SD = 29.97$, $M_{low\text{-}freq} = 50.86\%$, $SD = 33.10$; $z = 3.09$, $p = .002$, $r = 0.29$).

7.3. Design and procedure

The study utilized a one-way, two-level (high vs. low frequency gratings) within-participant design. Similar to Study 1, participants were presented a grating image and a pair of food images and were instructed to select the food that they felt best matched the grating image (a total of eight trials).

[5] M is the averaged proportion of trials that participants selected in high over low frequency grating image choices.

7.4. Results and discussion

Data were analysed using SPSS 22.0 for Windows (IBM SPSS Inc., Chicago, IL, USA). As the Shapiro-Wilk Normality test revealed that the null hypotheses of normal population distributions were rejected at $p < .05$, non-parametric statistical methods were used for subsequent data analysis.

A Wilcoxon signed-rank test was performed to determine whether participants differ in matching food images with low and high frequency grating images. Specifically, the percentage of healthy food selection was compared between images. As predicted, the results revealed that participants expected high (vs. low) frequency grating images to be associated with healthy (vs. unhealthy) foods ($M_{high\text{-}freq} = 35.09\%$, $SD = 32.68$, $M_{low\text{-}freq} = 24.12\%$, $SD = 30.24$; $z = 2.13$, $p = .03$; $r = 0.20$). The results confirm the generalization of the acoustic frequency effect to visual cues and association with food healthfulness. The implication of this novel finding will be discussed in the next section.

8. General discussion

The primary purpose of the study was to examine whether sogos composed with high (vs. low) frequency and with slow (vs. fast) tempo would be expected to be associated with healthy (vs. unhealthy) foods. The findings partially support the hypotheses and a robust effect of the high (vs. low) frequency sogos on the perception of food healthfulness was observed (Studies 1 and 2), while the effect of slow (vs. fast) tempo was at a marginally significant level (Study 1). The current study also provides initial evidence of the generalization of the frequency effect to the visual domain whereby high frequency grating images are also more associated with healthy foods (Study 3).

8.1. Sound frequency-healthfulness association

Our findings are in line with previous research suggesting a linkage between high frequency sounds and healthy food products (Motoki et al., 2021; Motoki et al., 2022; Peng-Li et al., 2021). For example, Peng-Li et al., 2021 demonstrated that listening to a 'healthy' (vs. 'unhealthy') soundtrack composed in high (low) frequency, slow (fast) tempo, and other features guided participants' attention towards healthier foods, and led to healthier food choice selections. Our findings further support the observation that frequency itself can potentially connote the attribute of healthfulness. Specifically, Study 1 demonstrated this phenomenon using two broad types of food categories (healthy vs. unhealthy foods) and the results revealed that sogos with high (vs. low) frequency and slow (vs. fast) tempo were expected to be more closely associated with healthy (vs. unhealthy) food products. In Study 2, we extended these findings using foods within the same category (healthy vs. less healthy burgers, healthy vs. less healthy salads) and only the effect of frequency was detected. Thus, sogos with high (vs. low) frequency are associated with healthy (vs. less healthy) foods, irrespective of the food category.

However, recent studies have revealed a boundary condition between tastes/flavors in the frequency effect and showed that listening to music composed in high frequencies (e.g., classic and jazz) evoked positive valence, which in turn appeared to increase preferences for sweet and healthier savoury foods (compared to rock/metal music) (Motoki et al., 2022). Furthermore, Motoki and colleagues (2021) demonstrated that hypothetical brand names containing high (vs. low) frequency sounds were rated as more appropriate for healthy savoury foods while there was no significant difference found in the sweet food category. It should be noted that food stimuli used in Motoki et al.'s study contained savoury and sweet foods in both healthy and unhealthy food categories which is not the case in our current study. This issue will be discussed in a later section.

In this study, the automatic association between high frequency stimuli and food healthfulness can possibly be explained by the shared semantic association between the features of frequency and food stimuli. We assume that high frequency sogos and healthfulness are preferably matched because both stimuli signify smallness and lightness, while low frequency and less healthful indicators are preferably associated because both features connote largeness and heaviness (e.g., Lowe & Haws, 2017; Motoki et al., 2021). Additionally, we also provide evidence using sogos that are matched for pleasantness, and also report no covariate effect of the tune familiarity (Study 1).

8.2. Sound tempo-healthfulness associations

Although there has been evidence that music consisting of slow tempo increased preferences towards healthy food items (Motoki et al., 2022; Peng-Li et al., 2021), no significant difference between the matching of healthy foods with slow versus fast tempo sogos was observed here. It is possible that our sogo stimuli were less complex than music stimuli used in the prior studies. Moreover, when the tempo is manipulated solely, its effect on consumer responses might differ from when it is mixed with other musical attributes. Perhaps the other auditory parameters (e.g., high vs. low frequency) override the effect of tempo on healthy food preferences when complex music is involved (Motoki et al., 2022; Peng-Li et al., 2021). Furthermore, previous research has demonstrated that tones with increasing tempo led to increased movement speed (Küssner et al., 2014). Much in line with research on food-related behaviours, participants chewed more rapidly when high (vs. low/no) tempo music was played (Roballey et al., 1985). Participants exhibited longer (vs. shorter) eating times when music was played at a slower (vs. faster) tempo (Mathiesen et al., 2020). Given this, it is plausible that tempo is more related to consumption rate (see Spence et al., 2019 for a review) rather than food perception and this might explain why solely varying tempo (while other parameters remain constant) does not differently influence association with healthy vs. unhealthy foods.

8.3. Visual frequency-healthfulness associations

While the previous literature has provided evidence of the cross-modal correspondence between high (vs. low) frequency musical tones with high (vs. low) spatial frequency images (Evans & Treisman, 2010), our findings extend this correspondence effect to high frequency-healthfulness associations in both auditory and visual stimuli. Specifically, in Study 3, the results confirmed that similar to high frequency sounds, high (vs. low) frequency images are matched with healthy (vs. unhealthy) foods. Given that grating images with high spatial frequency correspond to smaller stripes and finer detail, whereas low spatial frequencies represent larger stripes and coarseness (Bar, 2004), it is possible that the high (vs. low) frequency gratings connote healthfulness through the shared semantic meaning in a way similar to auditory stimuli. Collectively, high (vs. low) frequency stimuli (both auditory and visual) are crossmodally correspondent with healthy (vs. less healthy) attributes in food products.

9. Theoretical and managerial contributions

By linking frequency to healthfulness, this paper offers two specific contributions. First, the current study adds evidence to the extant literature on sound-healthfulness associations by providing evidence that sogos can shape the perception of healthy food amongst consumers by manipulating the stimulus frequency. Moreover, these findings generalize the sound frequency effect to visual stimuli by showing that high (vs. low) frequency images are also associated with healthfulness.

Second, the findings provide ideas to brand managers and their agencies who are seeking a novel sensory branding strategy for healthy food products. Specifically, we propose the application of cross-modal correspondences of high frequency sogos (and potentially slow tempo) to enhance the health appeal of foods. The effectiveness of sogos can be further augmented by congruent packaging or visual logos that use high frequency images (e.g., differing design of stripes or bars) to prompt consumers into making healthier choices without having to evaluate complex information often contained in the nutritional labels.

10. Limitations and future research directions

Firstly, although the findings imply how the inclusion of high frequency components in sogos could signify the healthfulness of food products, future research could further investigate whether and to what extent the effect generalizes to actual sogos which involves more compositional complexity (e.g., instrumental timbre, intensity fade up/down, pitch ascending/descending) (e.g., Mas et al., 2020). The fictitious sogos used in the current study (which comprised simple sound clips with varying frequency and tempo) were created with less complexity in order to control for potential confounds associated with naturalistic stimuli in the first instance. Future research could thus investigate the effect of sogos crafted with more complex parameters to gain further insights as to how combinations of music parameters can convey desired product attributes (including beyond the trait of healthfulness). Moreover, as the sogos used in this paper were manipulated in an experimental setting, adopting real brand sogos would perhaps increase the ecological validity of the findings.

Secondly, although high frequency is found to be associated with healthfulness, it is also linked with sweetness (e.g., Knoferle & Spence, 2012). Given that sounds differently influence the perception of sweet and savoury foods (Motoki et al., 2021; Motoki et al., 2022), it is interesting that somewhat differential results were obtained here. In Studies 1 and 3 we included both savoury and sweet foods in the healthy and unhealthy categories. Thus, it should be noted that our finding of high (low) frequency-healthfulness (unhealthfulness) association might have been partially influenced by the inclusion of sweet and savoury foods. In addition, in Study 2 all food stimuli used were savoury; hence, the frequency effect found here might have been partly affected by the saltiness of foods. However, it is important to note that since the sounds used in previous research were more complex than the current study, compositional complexity, (instead of frequency alone) may serve as a determinant for taste and healthfulness evaluations (Motoki et al., 2022). Nonetheless, before firm conclusions can be drawn, further investigations are required.

Thirdly, an intriguing clue to the biological basis of this effect comes from research showing how noises alter the taste perception of food being consumed (Yan & Dando, 2015). These authors explain that while the chorda tympani nerve carries taste information from the anterior portion of the tongue to the brain, it crosses the tympanic membrane of the middle ear. Loud noises temporarily disturb the transition of taste signals while they are crossing through the middle ear such that sweet taste signals become weakened and umami tastes become strengthened, leading to the altered perception of food tastes (Yan & Dando, 2015). Based on this observation, an interesting topic for future research would be to investigate the precise neural mechanisms underlying the association between frequency and perceptions of healthfulness. Given that they are possibly linked by some shared semantic association, the study of the neural correlates of semantic associations and conceptual similarity, in regions such as the anterior temporal lobe (Jackson, Hoffman, Pobric, & Lambon Ralph, 2015) would possibly help us gain more insight into how acoustic stimuli are crossmodally associated with such abstract concepts as healthfulness in the brain.

Fourthly, although at this point, we have introduced the new finding of visual frequency-healthfulness association, further research is needed to investigate whether adding a design of a high frequency grating image would enhance (i.e., the additive effect) the healthfulness appeal of a product. Further, our preliminary findings have yet to illuminate the boundary conditions under which these audio-visual frequency-healthfulness effects occur. Additional research is needed to investigate the moderating role of health concern/motivation on the implicit association between sogos and perceived healthfulness. Lastly, the current paper used only the piano to create sogos, future research could explore the role of timbre or other musical instruments on the perception of food healthfulness.

CRediT authorship contribution statement

Monin Techawachirakul: Conceptualization, Investigation, Visualization, Writing – review & editing. **Abhishek Pathak:** Methodology, Investigation, Writing – review & editing, Visualization, Supervision. **Gemma Anne Calvert:** Writing – review & editing, Supervision.

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.

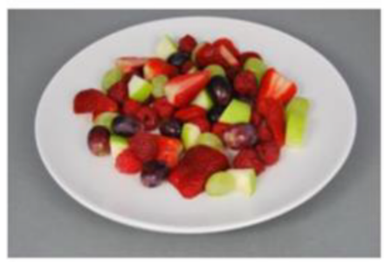
Appendix 1

Food images used in Study 1

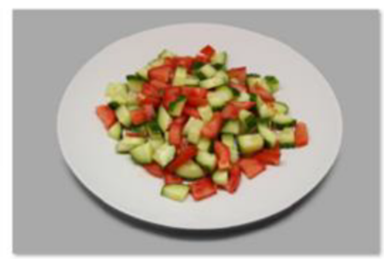
Healthy foods:

Green salad

Fruit salad

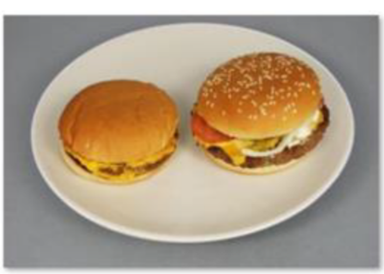


Cucumber and tomato salad



Unhealthy foods:

Cheeseburger



French fries

Chocolate cookies

Appendix 2

Food images used in Study 2

Burger:

Healthy burger (soy burger) Less healthy burger (bacon burger)

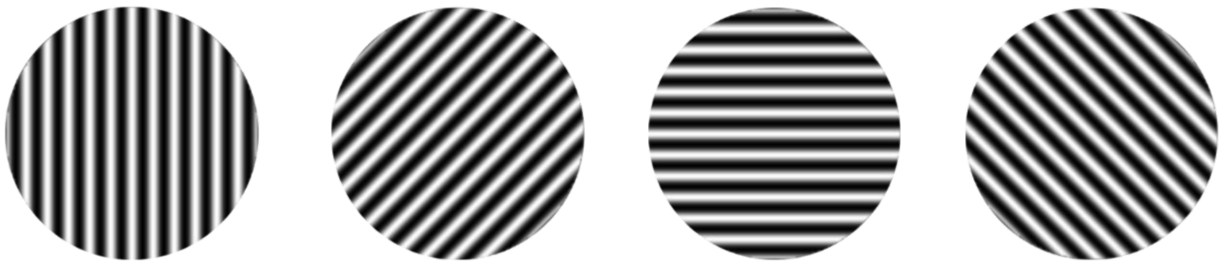
Salad bowl:

Healthy salad (spring salad) Less healthy salad (salad with fries)

Appendix 3

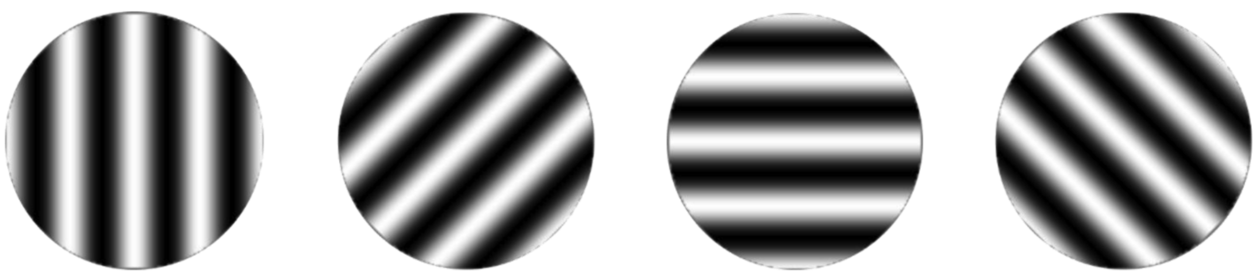
Visual stimuli used in Study 3

High-frequency sine-wave gratings (spatial frequency =12)

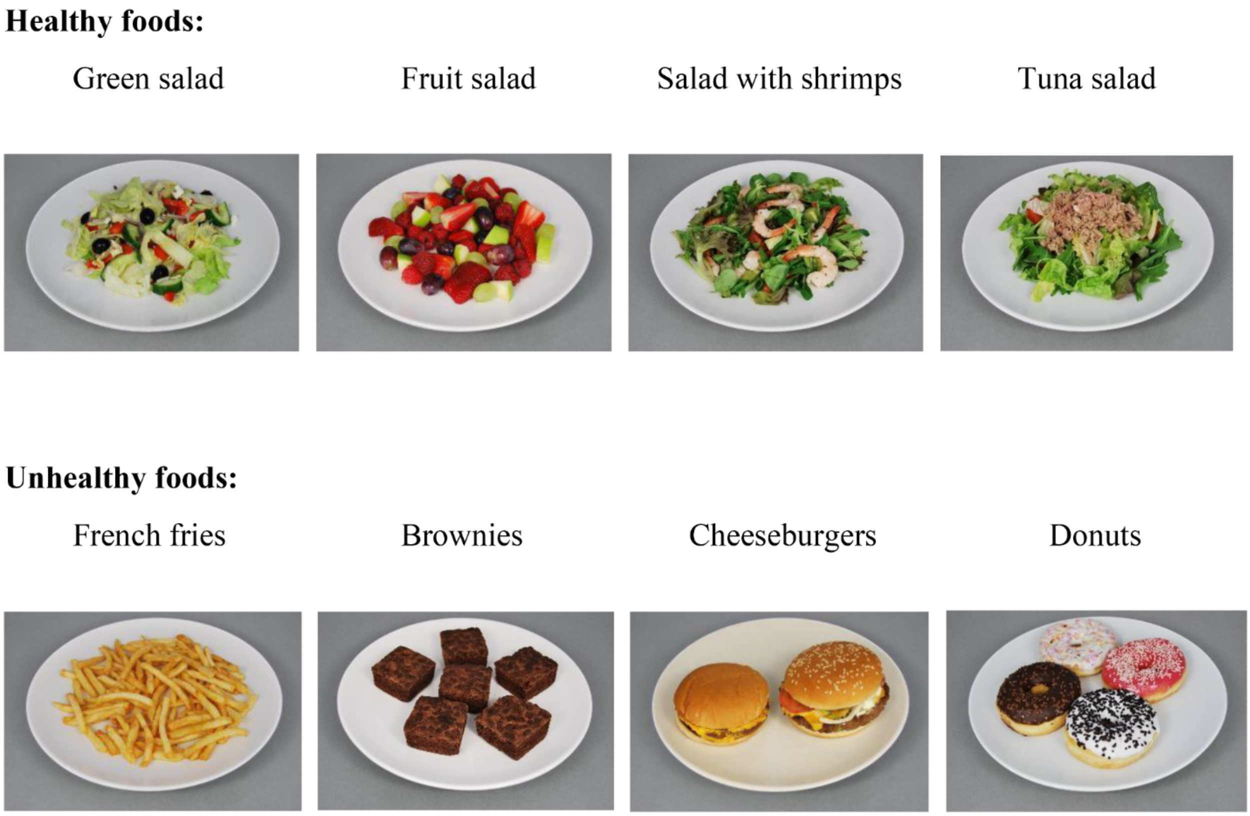


0° 45° 90° 135°

Low-frequency sine-wave gratings (spatial frequency = 4)



0° 45° 90° 135°



References

Bar, M. (2004). Visual objects in context. *Nature Reviews, Neuroscience, 5*, 617–629.

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

Bonde, A., & Hansen, A. G. (2013). Audio logo recognition, reduced articulation and coding orientation: Rudiments of quantitative research integrating branding theory, social semiotics and music psychology. *SoundEffects-An Interdisciplinary Journal of Sound and Sound Experience, 3*(1–2), 112–135.

Bronner, K., Frieler, K., Bruhn, H., Hirt, R., & Piper, D. (2012). What is the sound of citrus? Research on the correspondences between the perception of sound and flavour.

Bucher, T., Müller, B., & Siegrist, M. (2015). What is healthy food? Objective nutrient profile scores and subjective lay evaluations in comparison. *Appetite, 95*, 408–414. https://doi.org/10.1016/j.appet.2015.08.005

Charbonnier, L., van Meer, F., van der Laan, L. N., Viergever, M. A., & Smeets, P. A. M. (2016). Standardized food images: A photographing protocol and image database. *Appetite, 96*, 166–173. https://doi.org/10.1016/j.appet.2015.08.041.

Evans, K., & Treisman, A. (2010). Natural cross-modal mappings between visual and auditory features. *Journal of Vision, 10*. https://doi.org/10.1167/10.1.6

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191. https://doi.org/10.3758/BF03193146

Fenko, A., Lotterman, H., & Galetzka, M. (2016). What's in a name? The effects of sound symbolism and package shape on consumer responses to food products. *Food Quality and Preference, 51*, 100–108.

Goyal, S. (2019, April 2). *Sonic branding: How the sound of your brand can be a recipe for biz success.* Business standard. https://www.business-standard.com/article/economy-policy/sonic-branding-how-the-sound-of-your-brand-can-be-a-recipe-for-biz-success-119040200166_1.html.

Huang, X., & Labroo, A. A. (2019). Cueing morality: The effect of high-pitched music on healthy choice. *Journal of Marketing, 84*(6), 130–143. https://doi.org/10.1177/0022242918813577

Jackson, R. L., Hoffman, P., Pobric, G., & Lambon Ralph, M. A. (2015). The nature and neural correlates of semantic association versus conceptual similarity. *Cerebral Cortex, 25*(11), 4319–4333. https://doi.org/10.1093/cercor/bhv003

Kalloniatis, M. & Luu, C. (2007). Visual Acuity. In H. Kolb, E. Fernandez, & R. Nelson (Eds), *Webvision: The Organization of the Retina and Visual System [Internet]*. Salt Lake City (UT): University of Utah Health Sciences Center; 1995-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK11509/.

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

Krishnan, V., Kellaris, J. J., & Aurand, T. W. (2012). Sonic logos: Can sound influence willingness to pay? *Journal of Product & Brand Management, 21*(4), 275–284. https://doi.org/10.1108/10610421211246685

Landy, M. (2006, August 10). *Spatial frequency channels* [Lecture notes]. New York University. https://www.cns.nyu.edu/~david/courses/perception/lecturenotes/channels/channels.html.

Lee, A. Y., & Labroo, A. A. (2004). The effect of conceptual and perceptual fluency on brand evaluation. *Journal of Marketing Research, 41*(2), 151–165.

Lowe, M. L., & Haws, K. L. (2017). Sounds big: The effects of acoustic pitch on product perceptions. *Journal of Marketing Research, 54*(2), 331–346. https://doi.org/10.1509/jmr.14.0300

Lowe, M., Ringler, C., & Haws, K. (2018). An overture to overeating: The cross-modal effects of acoustic pitch on food preferences and serving behavior. *Appetite, 123*, 128–134. https://doi.org/10.1016/j.appet.2017.12.013

Mas, L., Bolls, P., Rodero, E., Barreda-Ángeles, M., & Churchill, A. (2020). The impact of the sonic logo's acoustic features on orienting responses, emotions and brand personality transmission. *Journal of Product & Brand Management, 30*(5), 740–753. https://doi.org/10.1108/JPBM-05-2019-2370

MasterClass. (2020, November 8). *Music 101: What is tempo? How is tempo used in music?* https://www.masterclass.com/articles/music-101-what-is-tempo-how-is-tempo-used-in-music#what-are-the-basic-tempo-markings.

Mathiesen, S. L., Mielby, L. A., Byrne, D. V., & Wang, Q. J. (2020). Music to eat by: A systematic investigation of the relative importance of tempo and articulation on eating time. *Appetite, 155*, 104801. https://doi.org/10.1016/j.appet.2020.104801.

Motoki, K., Park, J., Pathak, A., & Spence, C. (2021). Constructing healthy food names: On the sound symbolism of healthy food. *Food Quality and Preference, 90*. https://doi.org/10.1016/j.foodqual.2020.104157

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 Quality and Preference, 96*, Article 104380. https://doi.org/10.1016/j.foodqual.2021.104380

Pathak, A., Calvert, G. A., & Lim, L. K. S. (2020). Harsh voices, sound branding: How voiced consonants in a brand's name can alter its perceived attributes. *Psychology & marketing, 37*(6), 837–847. https://doi.org/10.1002/mar.21346

Peirce, J. W., Gray, J. R., Simpson, S., MacAskill, M. R., Höchenberger, R., Sogo, H., … Lindeløv, J. (2019). PsychoPy2: Experiments in behavior made easy. *Behavior Research Methods*. https://doi.org/10.3758/s13428-018-01193-y

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

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,* 105264-105264. https://doi.org/10.1016/j.appet.2021.105264.

Plasek, B., Lakner, Z., & Temesi, A. (2020). Factors that influence the perceived healthiness of food-review. *Nutrients, 12*(6). https://doi.org/10.3390/nu12061881

Reber, R., Schwarz, N., & Winkielman, P. (2004). Processing fluency and aesthetic pleasure: Is beauty in the perceiver's processing experience? *Personality and Social Psychology Review, 8*, 364–382. https://doi.org/10.1207/s15327957pspr0804_3

Reinoso Carvalho, F., Wang, Q., De Causmaecker, B., Steenhaut, K., Van Ee, R., & Spence, C. (2016). Tune that beer! Listening for the pitch of beer. *Beverages, 2*(4), 31. https://www.mdpi.com/2306-5710/2/4/31.

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

Toet, A., Kaneko, D., de Kruijf, I., Ushiama, S., van Schaik, M. G., Brouwer, A.-M., … van Erp, J. B. F. (2019). CROCUFID: A cross-cultural food image database for research on food elicited affective responses [Original Research]. *Frontiers in Psychology, 10*(58). https://doi.org/10.3389/fpsyg.2019.00058

Walker, P. (2016). Cross-sensory correspondences: A theoretical framework and their relevance to music. *Psychomusicology: Music, Mind, and Brain, 26*(2), 103–116. https://doi.org/10.1037/pmu0000130

Yan, K. S., & Dando, R. (2015). A crossmodal role for audition in taste perception. *Journal of Experimental Psychology: Human Perception and Performance, 41*(3), 590.

Zampini, M., & Spence, C. (2004). The role of auditory cues in modulating the perceived crispness and staleness of potato chips. *Journal of Sensory Studies, 19*(5), 347–363. https://doi.org/10.1111/j.1745-459x.2004.080403.x