



The sound of silence: Presence and absence of sound affects meal duration and hedonic eating experience

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ABSTRACT

The interplay between external auditory cues in the eating environment and cognitive processes, such as distraction, may influence food intake, but how and the degree to which they do is unclear. We report an experiment designed to investigate the effects of different sonic atmospheres on meal duration, food intake and evaluations, and responses to the sonic eating environment. In a quasi-naturalistic cafeteria setting, participants ($N = 248$) were eating a lunch meal whilst being in one of four conditions: slow music, fast music, cafeteria noise, and silence. The results revealed that participants eating their lunch while exposed to some kind of background sound spent more time on their meal than those eating in silence. In terms of music tempo, slow music prolonged meal duration compared to fast music, but did not lead to increased intake. The appropriateness and liking of the sonic atmosphere were positively correlated with the overall pleasantness of the eating experience and liking of the food. The findings provide support for existing evidence documenting the importance of ambient sound in relation to food experiences and provide further insights into how individuals perceive and respond to sonic meal environments. Results are discussed in terms of recommendations for future design of eating environments in different contexts.

1. Introduction

Food intake is a crucial topic of research across many different scientific disciplines, given the global prevalence of obesity- or malnutrition-related health issues and detrimental consequences of excess food production and food waste on the environment (Caldwell & Sayer, 2019; Egger & Dixon, 2014; Pack et al., 2007). Despite the focused research attention on this topic, there are still gaps in the knowledge on what predicts and determine food intake (Leng et al., 2017).

One branch of investigation shows that food intake rate may be related to hormonal mechanisms involved in appetite control. For instance, slower eating has been associated with decreased levels of postprandial concentrations of the “hunger hormone” ghrelin (Benelam, 2009; Kokkinos et al., 2010). In addition, the positive correlation between self-reported “fast eaters” and weight gain has been reported both with males (Tanihara et al., 2011), and females (Leong et al., 2011).

Other studies have shown that slower eating rates (compared with faster) of comparable meal sizes led to achieving satiation quicker (Azrin et al., 2008) and decreased energy intake (Andrade et al., 2008). Furthermore, increasing the number of chews before swallowing reduced meal size among normal-weight, overweight, and obese individuals (Zhu & Hollis, 2014) and increased metabolic rate following ingestion of food (Hamada & Hayashi, 2021).

Collectively, results from these studies suggest that interventions to promote slower eating may contribute to reducing food intake, control appetite, and prevent obesity. Yet, outside of clinical or behavioural therapy settings aimed at providing self-management strategies (Ben-ecke, 2002; Kaplan, 1980; Spiegel et al., 1991), broadly applicable interventions in natural eating environments have not been experimentally investigated.

The present study compares the potential effects of non-food related environmental sound stimuli on duration, intake, and evaluation of a lunch meal in a quasi-naturalistic multisensory cafeteria setting.

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1.1. Environmental cues influence food intake

Despite the lack of clear-cut methods to modify eating rate in real-world settings, growing research attention has been paid to the physical factors of multisensory eating or dining environments and their effects on various eating behaviours (Hoppu et al., 2020; Kontukoski et al., 2016). Among the many potential physical factors of the environment, acoustic and musical elements have been associated with eating-related changes in taste and flavour perception, eating behaviour, and food choices and experiences (Spence, 2012; Spence et al., 2019; Spence & Shankar, 2010). The temporal dimension of music in particular has attracted scholarly interest in terms of its impact on eating rate or meal duration in retail or hospitality settings.

1.1.1. Arousal

One common hypothesis is that musical tempo is a primary influence on arousal, which subsequently affects the execution of concurrent activities. In consumer research contexts, arousal is typically characterising the emotional response of calmness/excitement that a given environment elicits, where higher arousal corresponds to higher levels of activity (Mehrabian & Russell, 1974; Russell, 2003; Russell et al., 1981). With regards to background music, faster tempo is believed to increase arousal, resulting in activities being carried out more quickly (Smith & Curnow, 1966). Evidence supporting this hypothesis has been found in several studies where fast music consistently has been associated with faster eating and drinking, while slower music has been linked to more time spent eating and longer mealtimes (Caldwell & Hibbert, 1999, 2002; Mathiesen et al., 2020; McElrea & Standing, 1992; Roballey et al., 1985). A recent study demonstrated that subjects spent more time eating small pieces of chocolate when slow music was playing, compared to fast music (Mathiesen et al., 2020). However, the consumption context and food stimuli in this experiment lacked ecological validity.

One piece of research offering a slightly conflicting observation regarding arousal investigated different levels of music volumes and/or ambient restaurant sounds, which the authors termed “babble”, and their effects on behavioural intentions in a fine dining restaurant (Novak et al., 2010). Among the experimental sound environments, the condition with only “babble” was the most arousing, although not significantly so. Interestingly, arousal had no effect on behavioural intentions, including willingness to spend more time in the restaurant than planned (Novak et al., 2010). Whilst important to keep in mind these potential inconsistencies, it is relevant to note that the above-mentioned study reflects a preoccupation with the *intensity* rather than the type or composition of the sound. Thus, our first hypothesis seeks to validate the findings by Mathiesen et al. (2020); McElrea and Standing (1992); Roballey et al. (1985) that:

H1. Fast music will increase eating speed and reduce meal duration, whereas the opposite will hold true for slow music.

1.1.2. Distraction

The speed of eating ought to be relevant in terms of the volume of food consumed, but the implications of musical tempo in terms of food intake are as of yet insufficiently researched (Cui et al., 2021). Meanwhile, the presence of music, television, or other auditory media while eating is believed to be positively related to food intake (Stroebele & Castro, 2006), introducing the popular hypothesis that mealtime music may modulate intake by way of distracting from the eating activity (Bellisle et al., 2004; Benelam, 2009; Smith & Ditschun, 2009; Stroebele & De Castro, 2004; Stroebele & de Castro, 2006). The previously cited study by Mathiesen et al. (2020) provided some evidence that the presence of music relative to silence prolonged eating time, regardless of the type or music tempo. What remains unclear is whether or not the presence of *any* sound drives the differences in meal duration.

One study specifically investigating the role of sonic distraction was

conducted by Kaiser et al. (2016). The researchers assigned participants to experimental sound conditions differing in presumed familiarity (i.e., silent control, generic instrumental jazz, native language, and foreign language pop) in which they were eating a typical lunch meal. The authors hypothesised that higher familiarity with music would increase emotional arousal and distract attention from the meal, thus leading to higher food intake. However, the authors reported that only meal duration, not food intake, was affected by the sound conditions. Specifically, the group listening to native language pop spent less time on their meal. Since the authors failed to obtain familiarity ratings, nor any other evaluation of the music, it is impossible to infer to what the difference in meal duration was attributable. Considering the emotional arousal premise of the study, it is also striking that the authors did not account for any other potentially arousing factors of the music, such as tempo or rhythm, which indeed has been found to influence time-related factors of consumption experiences, not only eating time as mentioned above, but also more general perception of time (Kellaris & Kent, 1992). It is, therefore, conceivable to expect that some confusion between the two affective dimensions of arousal and pleasure could confound the results obtained by Kaiser et al. (2016). Finally, as was the case in the study by Mathiesen et al. (2020), the basis of comparison did not include non-musical sound among their experimental manipulations.

Following the notion that concurrent auditory stimuli could be distracting, and potentially interrupt interoceptive sensations of satiation, it is crucial to determine whether these effects remain significant in realistic eating settings, such as cafeterias and restaurants, especially where silence is rather unusual. From this perspective, juxtaposing music against an auditory backdrop, such as the sounds from a cafeteria, is warranted. By comparing four different sound conditions: silence, cafeteria soundscape, slow music, and fast music, our second hypothesis formally states that:

H2. Sound, as opposed to no sound, will increase meal duration.

1.2. Pleasurable experiences and music appropriateness

The previously established premise that internal feelings of hunger and satiety surrounding short-term ingestion episodes (meals) to a large extent determines when to initiate and terminate consumption aside, other important factors should be considered when studying food intake (Drewnowski & Bellisle, 2010; Hetherington, 2007). One broadly propagated factor is relevant to emphasise in the context of the present research, namely the idea that individuals' liking of the sensory properties, e.g., aroma, appearance, flavour, and texture of foods is a main driver of choosing and consuming food. Accordingly, sensory hedonics, i.e., eating for pleasure, is incontrovertibly linked to food intake (Mela, 2006; Yeomans, 2007). Related to this aspect, the notion that affective responses to one stimulus can transfer to the evaluation of another stimulus, sometimes referred to as “sensation transference”, has received some scientific interest (Spence et al., 2019). Evidence from one study suggests that higher pleasure evoked by background sound pressure level in a restaurant, in turn had a positive linear relationship against repeat patronage, recommending the place to others, and spending more time and money than planned in the restaurant (Novak et al., 2010). Similar results have been documented elsewhere in terms of background music liking and spending intentions (North & Hargreaves, 1996). Moreover, the more one likes the background music while eating, the more positively one will rate the taste, flavour, and pleasantness of foods (Kantono et al., 2016a, 2016b, 2018; Wang & Spence, 2018; Woods et al., 2011). However, to the best of our knowledge, no evidence currently supports the notion that music necessarily is preferred over any other type of sound present during a meal in a realistic consumption setting.

It has been shown that the level of appropriateness of the music within a situation will mediate the level of evoked pleasure (Areni & Kim, 1993; Wilson, 2003). In this regard, it is reasonable to assume that

ambient sounds of a cafeteria would be both familiar and appropriate in a lunch meal context. Therefore, we aim to investigate if the auditory mealtime atmosphere, whether silent, music, or cafeteria soundscape, contributes positively to the experiential aspects of eating. Our third hypothesis reads as follows:

H3. Overall hedonic rating of the eating experience is correlated with sound liking and appropriateness.

2. Methods

2.1. Participants

Two hundred and forty-eight participants (180 of whom identified as female, 65 as male, and 3 preferred not to disclose their gender), were recruited through social media posts, flyers, and via e-mail to participate in a multisensory study in exchange for a free meal. Ages of the participants ranged between 18 and 65 years old ($M = 39$, $SD = 12.5$). The subjects were told they would be eating their lunch inside a multisensory dining environment but were not told that the purpose of the study was to examine the effect of the sonic environment. Eligibility requirements covered age (18–65 years), and self-reported normal senses of vision, smell, taste, and hearing, as well as no allergies to the food served upon registering for the study. Participants registered for the study through an online form providing a general description, their rights as participants, and the handling of their data. They were instructed to not consume any food 2 h prior to starting the study. Participant characteristics are reported in [Table 1](#).

2.2. Materials and procedure

2.2.1. Auditory stimuli

The music used in this study was a playlist comprised of pre-recorded jazz instrumentals. The individual tracks were similar in compositional style and instrumentation, and while not being well-known, popular standards, were typical examples of the style, following [North and Hargreaves \(1998\)](#). This ensured familiarity with the genre but limited any potential effect of familiarity with specific pieces. Conventional jazz was chosen based on a previous online test, in which participants rated the appropriateness of different musical styles for eating out at a restaurant. Jazz, similar to the style used in the present study, was found

Table 1

Participant characteristics (means \pm SD). No significant group differences in age, mouth behaviour group, or baseline values of hunger/desire to eat and valence/arousal.

| Group | Silent | Cafeteria | Slow | Fast |
|-----------------------|------------------|-------------------|-------------------|-------------------|
| <i>n</i> | 61 | 62 | 63 | 62 |
| Men/Women/Other | 15/46 | 19/43 | 16/45/2 | 15/46/1 |
| Age | 39.33 \pm 12.2 | 37.42 \pm 12.23 | 38.03 \pm 12.03 | 41.05 \pm 13.66 |
| Mouth behaviour group | | | | |
| Cruncher | 30 | 29 | 27 | 32 |
| Chewer | 22 | 23 | 27 | 17 |
| Smoocher | 2 | 2 | 6 | 6 |
| Sucker | 7 | 8 | 3 | 7 |
| Baseline hunger | 7.04 \pm 1.75 | 7.34 \pm 1.75 | 6.76 \pm 1.72 | 7.25 \pm 1.87 |
| Post-meal hunger | 2.33 \pm 1.47 | 2.51 \pm 1.70 | 2.19 \pm 1.28 | 2.13 \pm 1.07 |
| Baseline arousal | 4.46 \pm 1.87 | 4.39 \pm 1.66 | 4.63 \pm 1.72 | 4.48 \pm 1.94 |
| Baseline valence | 6.61 \pm 1.51 | 6.82 \pm 1.73 | 6.79 \pm 1.50 | 6.61 \pm 1.70 |
| Post-meal arousal | 3.61 \pm 1.68 | 3.55 \pm 1.69 | 3.7 \pm 1.76 | 3.32 \pm 1.76 |
| Post-meal valence | 6.77 \pm 1.81 | 7.31 \pm 1.22 | 7.11 \pm 1.36 | 7.13 \pm 1.59 |

to be rated as most appropriate for this context ([Mathiesen et al.](#), under revision). Other research has shown that jazz music tends to be evaluated as pleasant ([Fiegel et al., 2014](#)) and attract moderate levels of attention in eating contexts ([Wilson, 2003](#)).

The cafeteria soundtrack consisted of two sound recordings from restaurant or cafeteria environments, mixed to one audio file of similar duration as the musical soundtracks.

All sound and music used in this study was retrieved from [epidemic sound.com](#), a royalty-free soundtrack providing platform. The playlists for the two music conditions were identical and compiled of 10 individual tracks (mean bpm = 99.7, $SD = 15.1$) before tempo modification. All tracks were modified to fixed tempos of 65 bpm for the slow music condition, and 160 bpm for the fast music condition. According to [Bruner \(1990\)](#), a range of 70–110 bpm reflects preferred tempos by most people, while tempos outside this range tend to be considered slow and fast, respectively. The tempo of each music playlist in our study can thus comfortably be considered as representatives of slow and fast music, and due to the great distance between the extremities, arguably produce a stronger manipulation.

Tempo modifications were carried out using the free, open-source audio software Audacity 2.3.1 for Mac. Pitch was unaltered by the tempo manipulation. Prior to the experiment, three non-musically trained university employees listened to samples of the music, and none reported any detrimental effects on overall sound quality due to the tempo modifications. All three soundtracks were subsequently normalised according to the ITU-R BS.1779-3 standard of loudness normalisation for audio broadcast using Adobe Audition 22.1.1.23. Musical pieces and cafeteria ambience recordings are listed in [Table A1](#).

2.2.2. Food stimuli

Identical salad boxes were provided for each participant. The salad consisted of iceberg lettuce, arugula, chicken breast, bread croutons, cherry tomatoes, slices of cucumber, dressing, a slice of bread and a 10 g packet of margarine spread. The salad itself was served in a clear plastic container, whereas the bread and margarine were provided in separate packaging. Alongside the food, participants received 250 ml of water measured using a volumetric flask and served in a clear drinking glass. Overall food intake was calculated as the difference between total weight of all listed items (i.e., food and water, including receptacles and packaging) weighed prior to participants arriving and again after participants had left. Nutritional composition and details of the meal are described in [Table A2](#) and depicted in [Fig. 1](#).

2.2.3. Study facility and environment

The study was conducted in the Flavoria® research restaurant in Finland. The room was a 94 m² rectangular room, and the temperature inside was held consistently at 21 °C on all study days. A 7.1 surround sound speaker system was installed in the ceiling, alongside 60 adjustable lights. During all study days, an image of the empty outside cafeteria area was projected onto the right-hand wall, while the left-hand wall was neutral. The image was projected to visually imply the intended setting of the study, i.e., a cafeteria. The capacity of the room was set at ten persons according to Covid-19 space limitations; thus, ten individual tables were distributed in two rows lengthwise inside the room. A small kitchen area was located in one end of the room, shielded off by a room divider. Food-related activities, including weighing, was conducted behind this divider out of sight of the participants. The physical study setup is depicted in [Fig. 1](#).

In the no-sound condition, the average sound pressure level (L_{Aeq} = Equivalent Continuous Sound Level) of the empty room was 40 dBA, which is considered a relatively quiet room, akin to a room within which only ventilation noise is heard ([Pulkki, 2019](#)). While our participants did eat with others present, subjects did not interact with each other and did not generate much additional sound inside the room. Average SPL for all sound conditions was set to 48,6 dBA ($SD = 0.6$), similar to the conditions used by [Kaiser et al. \(2016\)](#). At this level, the soundtracks were



Fig. 1. Food stimuli (left): Caesar chicken salad lunch meal (average food portion weight presented to participants: 471.5 g ($SD = 25.8$), including bread (~25 g), margarine (10 g), and packaging (~40 g). Meal composition: approximately 50 g cherry tomatoes, 30 g dressing, 60 g cucumbers, 80 g chicken, 140 g salad leaves, 15 g parmesan, 10 g rucola, 10 g croutons. Study facility (right): Individual dining tables with iPads and cafeteria wall projection.

clearly audible and maintained high fidelity, while not being overstated. Sound pressure levels in the study facility were measured in the centre of the room on all days before participants' arrival to ensure sound playback volume was consistent for all conditions. Measurements were obtained using an NTi XL-2 handheld audio and acoustic analyser with an M4261 measurement microphone.

2.2.4. Procedure

The present study was conducted according to the guidelines of the Declaration of Helsinki. Written consent was obtained on the study day before beginning the experiment. Data collection took place on weekdays during normal lunch hours between 10:30–13:00 in October and November of 2021. In the sound conditions, music was playing the entire time that participants were present in the room. Upon arriving to the study, participants were placed individually at single tables, each equipped with an iPad as well as the complete lunch meal; a glass of water; cutlery and napkin; a container for used facemasks, as well as a new facemask. They were asked to follow the instructions in the questionnaire and informed that they could eat for as long (or short) and as much (or little) as they wanted, similar to the study by Kaiser et al. (2016). After completing the survey, they were offered an additional piece of chocolate or candy and a coffee or tea as reward. An experimenter was present to assist participants with technical issues and/or questions during the study.

2.2.5. Survey flow and measures

The questionnaire was designed using the online Qualtrics platform. The procedure is visualised in Fig. 2, and all questions and scale structures are detailed in Table 2. All participants were asked for their informed consent via the introductory slide in the survey, which they provided before beginning the study. Upon agreeing to partake, baseline information about emotional state and desire to eat was obtained. Participants rated their general hunger levels at baseline and after they had finished their meal using four questions developed by Duerlund et al. (2021). To measure participants' pre- and post-meal emotional states, a simplified version of the circumplex model of emotion developed by Russell et al. (1981) was applied, with responses recorded on one scale for arousal and one for valence.

Participants were then instructed to prepare to eat by opening the salad box. Confirming this action, participants pressed the button "yes"

after which a prompt would appear, asking them to start eating. A hidden timer in the questionnaire would start at this moment. The prompt also instructed participants to return to the iPad once they had finished the meal. When confirming they had finished the meal via a button, the timer would stop counting. The main dependent variable of the study, eating time, was thus measured by recording the time between participants opening the salad box and their own decision to conclude the meal.

After eating, the participants were asked to evaluate their meal experience, hunger level and emotional state, as well as their experience of the sonic atmosphere. Finally, participants were asked to provide demographic information, including self-reported age and gender, and with which mouth behaviour group they most identified (i.e., chewer, cruncher, smoocher, sucker) in the form of an adapted version of the mouth behaviour questionnaire (Jeltema et al., 2014, 2015, 2016). This measure was included to take into account individual differences in participants' general eating styles, such as mastication tendencies and oral processing of foods, previously used in a similar study by Mathiesen et al. (2020), who observed a trend where self-reported mouth behaviour group correlated with eating speed.

2.3. Data analysis

A between-participants design was used, where eating duration was the main dependent variable and sound types were the experimental manipulations. Eating duration (measured in seconds) was calculated for each participant by subtracting the time of finishing the meal from beginning the meal.

To assess the overall influence of sound condition on the main experimental measures of meal duration and food intake, one-way analysis of co-variance (ANCOVA) were conducted with meal duration (or food intake) the as dependent variable, while sound condition was used as the independent variable. Participants' self-reported baseline hunger level was processed as a covariate. Separate ANCOVA's comparing tempo of the music conditions as well as comparing sound and no sound were performed to explicitly test H_1 and H_2 .

Relationships between participants' evaluation of the sonic atmospheres and their meal experience pertaining to H_3 were assessed by calculating Pearson correlations. To further examine differences in participants' response to the sonic atmospheres, A multivariate analysis

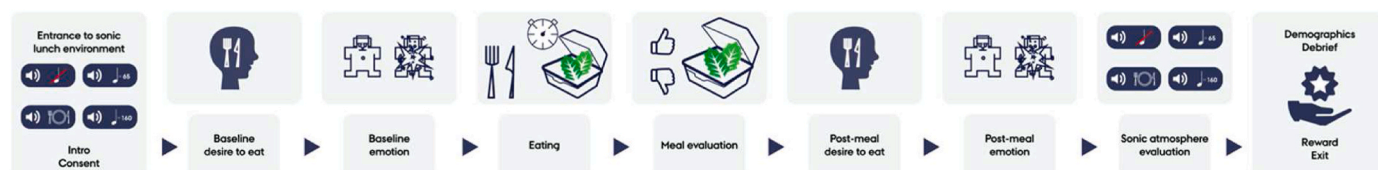


Fig. 2. Survey flow and experimental design.

Table 2
Survey questions and scale items.

| Measure | Question phrasings and statements | Scale structure and answer options |
|-----------------------------|---|---|
| Hunger/desire to eat | How much do you desire to eat something right now? How full are you right now? How much do you need food right now? How hungry are you right now? | 10 cm Visual Analogue Scale 0 = Not at all Extremely = 10 |
| Emotional state | Please indicate on the scales below how much do you currently feel the following emotions: | 9-point scales |
| Arousal | | 1 = Calm, relaxed Excited, energised = 9 |
| Valence | | 1 = Displeased, negative Pleased, positive = 9 |
| Meal evaluation | How much did you like the salad? How pleasant was your overall eating experience? How much did you pay attention to the food in general (e.g. the taste, the flavour, the texture)? How much did you pay attention to your own eating actions (e.g., picking up the fork, chewing, swallowing)? How much did you pay attention to the presence of others in the dining environment? | 1 = Not at all Extremely = 9 |
| Sonic atmosphere evaluation | How much do you like the sonic atmosphere in the dining area? How much attention did you pay to the sonic atmosphere in the dining area during eating? How appropriate is the sonic atmosphere for eating a meal? | |
| Demographics | | Self-report/one choice |
| Gender | | |
| Age | | |
| Mouth behaviour group | When you eat, which of the following descriptions best matches you? | |
| Cruncher | I like to crunch my food fast and forcefully | |
| Chewer | I like to chew my food for a long time | |
| Smoosher | I like to mash the food into a soft mass | |
| Sucker | I like to suck out the flavour of the food before chewing or swallowing | |

of covariance test (MANCOVA) with sound condition as independent variable was conducted on ratings of attention to sound, liking for sound, and appropriateness of the sound. Similarly, a MANCOVA was conducted with overall sound condition as independent variable and experiential measures of eating (liking of food, pleasantness of the eating experience, attention to the taste/flavour of the food, attention to eating actions, and attention to others).

All analyses were performed using IBM SPSS Statistics Version 28 for Mac using $\alpha = 0.05$. Significant main effects were followed up by post-hoc means comparisons using the Bonferroni correction. Associated

effect sizes are reported using partial eta-squared (η_p^2).

3. Results

3.1. Overall effects of sound condition on eating time and food intake

The one-way ANCOVA analysis showed a significant main effect of sound type on meal duration ($F_{3,244} = 3.56, p = .015, \eta_p^2 = 0.04$). Pairwise comparisons revealed that the silent group ($M = 716.09, SE = 29.26$) ate their lunch meal significantly faster than did the slow music group ($M = 840.48, SE = 28.92$). Specifically, a mean difference of -124.39 s was observed between these groups ($SD = 41.11, p = .016$). However, no other significant differences were found between the groups (Fig. 3a).

The ANCOVA for the difference in overall meal intake of food and water indicated no differences between the groups ($F_{3,244} = 0.47, p = .828$) (Fig. 3b). Mean overall intake across groups was 598.94 g ($SD = 90.66$), corresponding to 83% of the provided portion. On average, participants ate 391.51 g ($SD = 66.15$) of the food and drank 207.51 ml ($SD = 55.91$) of the water.

3.1.1. Effect of tempo

To explicitly investigate H_1 , planned ANCOVA's between the slow and fast tempo conditions revealed a significant effect of music tempo on eating duration ($F_{1,123} = 5.71, p = .018, \eta_p^2 = 0.04$), where eating duration was longer during the slow tempo compared to the fast tempo ($M_{\text{slow}} = 841.2, SE_{\text{slow}} = 29.37, M_{\text{fast}} = 741.06, SE_{\text{fast}} = 29.61$) (Fig. 3c). In contrast, there were no differences in meal intake between the slow and fast tempo groups ($F_{1,123} = 0.04, p = .845$).

3.1.2. Effect of sound vs. silence

To explicitly investigate H_2 , planned ANCOVA's comparing the silent condition against all other sound conditions revealed that meal duration was significantly shorter when no sound was present ($F_{1,244} = 4.67, p = .032, \eta_p^2 = 0.02$), specifically $M_{\text{no_sound}} = 715.98, SE_{\text{no_sound}} = 29.50, M_{\text{sound}} = 789.38, SE_{\text{sound}} = 16.84$. No differences in meal intake were observed ($F_{1,244} = 2.05, p = .15$) (Fig. 3d).

3.2. Experiential evaluations

To explicitly investigate H_3 , Pearson correlations revealed a positive relationship between ratings of liking for the sonic atmosphere and liking for the meal ($r_{248} = 0.13, p = .042$) and the overall pleasantness of the eating experience ($r_{248} = 0.38, p < .001$), as well as between the appropriateness of the sound and the overall pleasantness of the eating experience ($r_{248} = 0.36, p < .001$). Moreover, a significant positive correlation between attention to sound and attention to food ($r_{248} = 0.19, p = .002$) was observed.

In terms of participants' ratings of the different sound conditions, the MANOVA revealed an overall effect on all three measures related to the sonic atmosphere ($F_{3,244} = 15.87, p < .001, \eta_p^2 = 0.34$). More specifically, sound condition had a significant effect on attention to the sonic atmosphere ($F_{3,244} = 18.56, p < .001, \eta_p^2 = 0.19$), liking of the sonic atmosphere ($F_{3,244} = 34.61, p < .001, \eta_p^2 = 0.30$), and appropriateness of the sonic atmosphere ($F_{3,244} = 22.48, p < .001, \eta_p^2 = 0.22$). Pairwise comparisons revealed that mean scores for attention to the sound were significantly lower in the slow music condition ($M = 4.57, SE = 0.25$) than all other sound conditions (all $p < .001$); that liking for the silent ($M = 3.62, SE = 0.28$) and slow ($M = 4.41, SE = 0.27$) conditions were significantly lower than for the cafeteria ($M = 6.15, SE = 0.27$) and fast music ($M = 7.16, SE = 0.27$) conditions (all $p < .001$); and that the appropriateness of the sonic atmospheres was significantly higher for the fast ($M = 7.53, SE = 0.27$) and cafeteria ($M = 6.71, SE = 0.27$) conditions, than for the silent ($M = 4.9, SE = 0.27$) and slow conditions ($M = 5.06, SE = 0.27$), (all $p < .001$) (Fig. 4a).

The MANCOVA for differences in hedonic evaluations of the meal

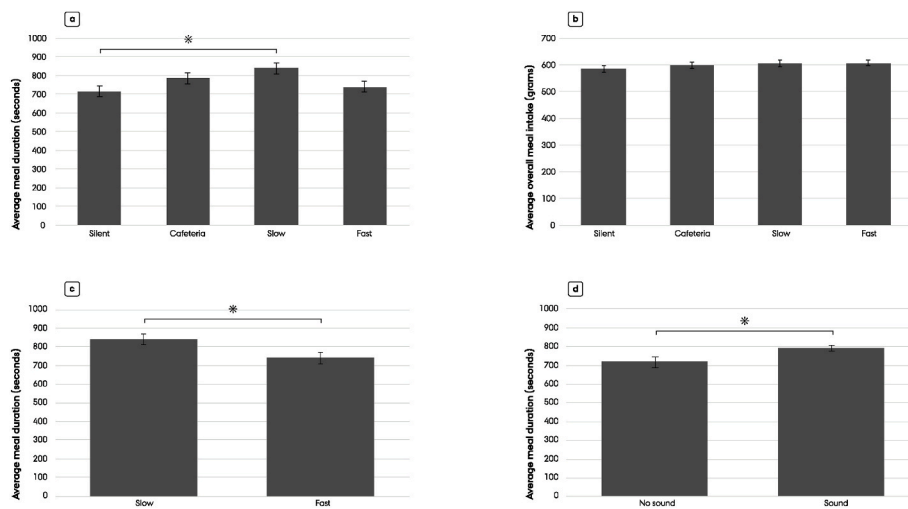


Fig. 3. The effects of sound condition on average meal duration (a); average overall meal intake of food and water (b); H1 testing: the effects of tempo on average meal duration (c); H2 testing: the effects of no sound vs. sound on average meal duration (d). Error bars represent standard error of the mean. Mean values with an * indicates a p-value less than 0.05.

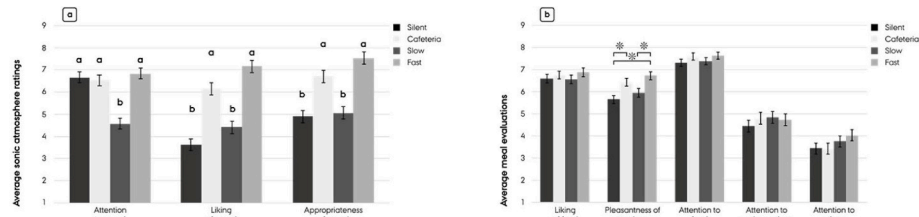


Fig. 4. Average sonic atmosphere ratings (a); and average meal evaluation (d). Error bars represent standard error of the mean. Mean values with an *, or unlike letters (a, b) indicates a p-value less than 0.05.

indicate that only the overall pleasantness of the mealtime experience was affected by the sonic atmosphere ($F_{3,244} = 6.21, p < .001, \eta_p^2 = 0.07$). Post hoc comparisons showed that participants in the fast music ($M = 6.71, SE = 0.19$) and cafeteria groups ($M = 6.42, SE = 0.19$) rated pleasantness significantly higher than participants in the silent condition ($p < .001, p = .026$, respectively), which obtained the lowest mean values of pleasantness ($M = 5.64, SE = 0.19$). Furthermore, pleasantness ratings in the fast music group were significantly higher, than those in the slow music condition ($M = 5.95, SE = 0.19, p = .031$) (Fig. 4b).

4. Discussion

Existing research has established a positive relationship between the presence of music and food intake (Kaiser et al., 2016; Stroebele & De Castro, 2004; Stroebele & de Castro, 2006), and between music tempo and consumption speed (Caldwell & Hibbert, 1999, 2002; McElrea & Standing, 1992; Roballey et al., 1985). However, what has not yet been examined is whether differences in music tempo or the presence of any type of sound is the more plausible explanation for longer meal duration and potential intake. We presented an experiment testing the differences between silent, cafeteria, slow, and fast music sonic eating environments on the way in which food is consumed, experienced, and evaluated.

4.1. Meal duration and arousal

As predicted, our findings showed that meal duration differed significantly between slow and fast music conditions (H₁), thus supporting the prevailing theory that more arousing stimuli increases physiological and energetic activity (Yerkes & Dodson, 1908) and (temporarily) influences performance on concurrent tasks such as the

shopping pace through a supermarket (Smith & Curnow, 1966), timing of motor actions (Repp, 2006), or running pace on a treadmill (Edworthy & Waring, 2006). Furthermore, our results replicate earlier evidence that fast music tempo decreases, whereas slow music increases consumption time (McElrea & Standing, 1992; Roballey et al., 1985), and validates a previously employed time measurement methodology in a more ecologically valid setting (Mathiesen et al., 2020). However, looking at the overall effects of sound type, the idea that arousal alone is accountable for the differences in meal duration is less plausible and does not explain why the meal durations of the presumably most and least arousing sound conditions (i.e., fast music and silence) produced similar meal durations. The self-reported baseline and post-meal arousal measurements were directed at participants' overall emotional state and did not allow for a specific rating of the arousing quality of the sonic atmospheres. In addition, we obtained participants' baseline arousal ratings after they had entered, and thus potentially had become accustomed to, the experimental setting. Therefore, we cannot infer on the arousing potential of the sonic atmospheres in comparison with the environment outside of the study facility. Future research should examine this in more detail.

4.2. Meal duration and distraction

Another perspective that could account for the observed effects is the notion that the allocation of cognitive resources can be modified by the presence of environmental stimuli. Following this line of thought, the presence of sounds adds to the amount and complexity of information to be processed in the environment, resulting in attentional interference towards the activity at hand. Our findings showed that meal duration increased in the conditions where sound was present, compared with the

silent condition (H₂) thus indicating that the presence of sound of any kind is likely to prolong meal duration, supporting the distraction hypothesis and the evidence provided by previous research (Kaiser et al., 2016).

It would be tempting to conclude that the more attention allocated towards external stimuli, the less focus will be paid to the eating activity and the food, resulting in distracted eating, prolonged meal duration, and potentially increased intake as proposed by extant literature (Ben-elam, 2009; Stroebele & De Castro, 2004; Stroebele & de Castro, 2006). Our results do not indicate any such effect. In fact, looking into attention responses to the sonic atmospheres encourages critical reflection upon this theory. First of all, participants in our study rated their attention towards the slow music condition significantly lower, compared with all other groups. Conversely, this condition produced the longest meal duration. On the other hand, most attention was paid to the fast music, followed by the silent and cafeteria conditions, which produced shorter meal durations than slow music. This suggests that the distraction hypothesis alone is a poor explanation for the relationship between meal duration and the presence of background sound, since the condition which attracted the most attention also yielded the shortest meal duration.

Our findings emphasise the existing inconsistencies in available literature as to the specific effects of sonic distractors on cognitive performance. In one study for instance, improvements in memory was observed when subjects were listening to music of low arousal, compared to high arousal (Nguyen & Grahn, 2017), while another study found that fast and loud background music impeded reading comprehension, whereas slow and soft music had no detrimental effects (Thompson et al., 2011). A third example suggested that the pleasure associated with a musical experience mediated the effect on cognitive performance, such that increased enjoyment improved memory recall (Lim & Park, 2019).

Approaching the issue of distraction from a slightly different perspective could provide additional insights. For example, research has shown that mindful and attentive eating, i.e., enhanced awareness of one's eating behaviour or focus on the sensory properties of food, may encourage people to more carefully monitor intake and respond to physiological sensations such as hunger and satiety, and derive more pleasure from eating (Dalen et al., 2010; Hong et al., 2012; Tapper et al., 2018). Thus, more attention to the food itself and the act of eating could be hypothesised to prolong meal duration and possibly reduce future intake (Robinson et al., 2013). Although we did not observe a relationship between attention to food and meal duration, we encourage future research to investigate the intricacies of attentional processes involved in eating to provide a more comprehensive understanding of this topic.

4.3. Food intake

Despite the otherwise compelling suggestion by existing literature (e.g., Bellisle & Dalix, 2001; Bellisle et al., 2004) that concurrent auditory distractions while eating increases food intake by reducing attention towards the meal, this observation was not detected in our study. The fact that we did not observe differences in food intake may be attributable to the fact that participants were served a single, predefined portion of food. The meal in question was a standardised and normal-sized serving provided by the university cafeteria food service. The pre-packaged portion may have signalled to participants to finish their meal, and it is thus unlikely that people would leave a considerable amount of food behind. Likewise, since subjects were served only one portion, it was not possible to consume additional food while the study was ongoing. However, considering that participants on average consumed ~83% of the meal, this indicates that the portion size was appropriate for the intended occasion. We encourage future studies offering participants ad libitum food to eliminate the potential effect of the pre-determined portion size on food intake.

It is also worth pointing out that although food intake was seemingly unaffected by the sonic environments, meal duration differed significantly among the conditions, notwithstanding the consistent meal size. This is of high relevance because the manner in which food is eaten is believed to influence consummatory behaviour across time (Leong et al., 2011; Tanihara et al., 2011). More specifically, commensurate meals consumed at varying speeds may impact appetitive state longer term and thus moderate subsequent food intake. We were not able to record later food intake for our participants, and it is, therefore, crucial that future research investigates this aspect.

4.4. Experiential evaluations

Liking for the fast music and cafeteria soundscape corresponded with higher pleasantness ratings of the overall meal experience. This finding expectedly supports existing evidence that liking for the background sound while eating is associated with increased pleasure of the eating experience (Kantono et al., 2016a, 2016b, 2018; Wang & Spence, 2018; Woods et al., 2011). However, the four sound conditions did not modulate liking of the food itself.

Evaluative ratings of the sonic atmospheres alone generated interesting results. Liking was highest for the fast music, followed by the cafeteria soundscape and both were significantly higher than the slow and silent conditions. Higher liking for faster music correspond to suggestions from music perception and psychology studies that faster tempo music tends to be preferred above slower music (Geringer et al., 2006; LeBlanc et al., 1988).

More surprising was the finding that the slow music produced the lowest liking ratings of the conditions involving sound, particularly in light of the fact that the musical material was identical. Even more peculiar, the slow music obtained significantly lower ratings of attention than all other groups. These findings could be consistent with Berlyne's inverted-U model of preference of music as a function of *collective* properties of stimuli, such as surprisingness and complexity, which raise arousal (Berlyne, 1971). According to this theory, liking for music will peak at the point where the music produces an optimal level of arousal through its structural properties (Chmiel & Schubert, 2017). Previous research has suggested that high arousal music typically has a larger number of informational events per unit of time, and thus is more rapidly changing, than low arousal music (Banbury et al., 2001; Jones et al., 2000; Nguyen & Grahn, 2017) and may thus be perceived as more complex. Manipulating the tempo of the music in our study could produce such an effect, where flow and progression in the slow music was reduced. The low attention and liking ratings for the slow music could thus be explained by its sparseness and low amount of changing information and as a result have been experienced as cognitively under-stimulating to participants.

This begs the question why attention to the silent atmosphere was significantly higher than the slow music. However, it is likely that the (relative) absence of sound was unusual in an eating context thus becoming conspicuous and incurred attention.

4.5. Implications

The results of our study have clear practical impact. In particular, they have important implications for the understanding of sound influences on eating behaviour and experience in a range of public and domestic eating settings alike. While there are many potential sensory stimuli that can be implemented in a food service setting, our study showed that sound is capable of producing substantial experiential effects, while being relatively cost-efficient and requiring little infra-structural change.

First, there would appear to be many reasons for fine dining establishments to enhance or facilitate memorable and enjoyable customer experiences, such as increasing the likelihood of return patronage or the willingness to spend more money. Managers of lunch restaurants and

work-place canteens may use music to provide a more enjoyable dining environment for workers, who increasingly seem to appreciate efforts to make the everyday “unnoticed” lunch meal an experience (Hynynen et al., 2021). Our observation that the overall pleasure of the experience was correlated with the liking for the sonic atmosphere is thus of relevance to restaurateurs and other food service providers. This result indicates that between otherwise identical music, it is first and foremost the arousal properties, in this case tempos, that are likely to determine the degree of preference and liking for the sound. Moreover, the liking for the sonic atmosphere seems to be an important parameter in the overall liking of the eating experience. In the case of our study, cafeteria sounds and fast music were liked significantly more than slow music and no sound. Although future studies should investigate these effects among a broader range of musical genres and types of sound, we propose that managerial decisions should begin by evaluating the arousal potential as well as the preference of the auditory stimuli used in their establishments to maximise their specific goals.

Second, the overall finding that ambient sonic cues affect meal duration provides incentive for health care professionals to incorporate sound into the design of both existing and future eating environments in hospitals, nursing homes, or other care facilities. Furthermore, for care providers invested in optimising nutrition among institutionalised patients at risk of malnutrition, playing music of different tempos or implementing other sounds may stimulate (or sedate) physiological (e.g., motor control, chewing) as well as cognitive (e.g., perceptual, attentional) processes involved in eating and known to impede or exacerbate intake.

4.6. Limitations

We attempted to design a quasi-naturalistic setting resembling a typical workplace cafeteria in order to examine the effects of sonic atmospheres, while being able to control as many confounding elements as possible. One limitation of this setup was that the controlled aspects of the experiment may have been perceived as artificial to the participants, such as the requirements of eating solitarily and not interacting with others present during the study. While the ability to interact with others and eating lunch in groups is highly valued by Finnish consumers, so is the ability to have lunch alone, undisturbed (Hynynen et al., 2021). Considering that our participants were sampled from a Finnish population, this supports the ecological validity of our results.

We should acknowledge the fact that we assumed the arousal potential of the music based on earlier research (Mathiesen et al., 2020; McElrea & Standing, 1992; Roballey et al., 1985), and did not employ concrete measures of arousal responses to the sonic environments. Future studies could benefit from using validated measures of arousal such as galvanic skin response, heart rate or other implicit techniques to circumvent cognitive biases in self-reports.

Likewise, we did not record dietary or health-related demographic information such as personal diet, BMI, income, educational level, or cultural background, which could be potential moderators of food intake. However, as we did not observe any differences in food intake, these factors likely did not influence our results. Relatedly, the gender distribution of our sample was skewed towards females. Although we did not observe any differences in neither food intake, nor meal duration across genders, this may be attributable to the fixed meal size as noted earlier. We advise future research to study these aspects using a more gender-balanced study population. Despite these limitations, we argue that ecological validity is strengthened in our study compared with similar previous studies of eating behaviour by providing a physical setup resembling a cafeteria, offering a realistic meal size, and by using

pre-recorded musical material played over speakers in a manner not inconceivable to encounter in real-world dining environments.

5. Conclusion

The present study demonstrates that both explicit evaluations and implicit behaviours of eating are affected by structural musical elements. Our study confirms the existing assumption that music tempo alone affects meal duration in a setting reflecting the characteristics of a real-world lunch environment, regardless of the level of enjoyment derived from the sound or the food. Furthermore, the study offers additional empirical insights into the nuanced interrelationships between different sonic atmospheres and the eating experience. This has important implications in a variety of contexts, particularly where time-related and hedonic aspects of eating are of relevance, such as stimulating or counteracting fast or slow eating, or improving the mealtime experience. Taken together, it is vital that each specific use case takes into account the overarching goal of the sonic atmosphere, whether it is to encourage faster or slower eating, or to provide a more enjoyable experience.

Ethical statement

The Flavoria study protocol was reviewed and ethically approved by the Ethics Committee for Human Sciences at the University of Turku, Humanities and Social Sciences Division (37/2021). The study followed the European Union’s General Data Protection Regulation (GDPR).

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Author contributions

Mathiesen, S.L.: Conceptualisation, Methodology, Data curation, Data analysis, Writing- Original draft preparation. Hopia, A.: Writing- Reviewing and Editing. Ojansivu, P.: Methodology, Writing- Reviewing and Editing. Byrne, D.V.: Supervision, Writing- Reviewing and Editing. Wang, Q.J.: Conceptualisation, Methodology, Data curation, Data analysis, Writing- Original draft preparation. All authors have approved the final article.

Data availability

The data presented in this study are available on request from the corresponding author.

Declaration of competing interest

The authors declare no conflicts of interest.

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Appendices.

Table A1

Musical and soundscape material used in the study, retrieved from [epidemicsound.com](https://www.epidemicsound.com). Permission to use audio material was obtained from Epidemic Sound.

| Sound type | Artist/producer | Name | Original bpm | Link |
|------------|-------------------|------------------------------------|--------------|----------------------|
| Cafeteria | SFX Producer | Restaurant Diner 1 | N/A | Link |
| | SFX Producer | Restaurant Ambience Without Voices | N/A | Link |
| | SFX Producer | Pair Cafeteria | N/A | Link |
| Music | Nocturnal Spirits | A Figure of Speech | 116 | Link |
| | Oakwood Station | Camper's Day | 106 | Link |
| | Nocturnal Spirits | Greene St. | 80 | Link |
| | Nocturnal Spirits | If You're Weary | 100 | Link |
| | Nocturnal Spirits | In Our Younger Years | 72 | Link |
| | Nocturnal Spirits | Last Time We Kissed | 115 | Link |
| | Wendy Marcini | Late Night Dinner | 92 | Link |
| | Nocturnal Spirits | Not That Serious | 99 | Link |
| | Nocturnal Spirits | One Less Lonely Man | 117 | Link |
| | Bladverk Band | Memories from the Past | 100 | Link |

Table A2

Food stimuli: Chicken salad (~395 g) composition and nutritional content per 100 g. Average portion weight: 471.5 g ± 25.8, including bread (~25 g), margarine (10g), receptacles, and packaging)

| Nutrients | Amount | Unit |
|-----------------------|---------------|-------------|
| | Chicken salad | Bread slice |
| Energy content (KJ) | 292.74 | 1037 |
| Energy content (kcal) | 70.47 | 247 |
| Fat | 3 | 1.8 |
| Saturated | 1.26 | 0.3 |
| Monounsaturated | 0.55 | |
| Polyunsaturated | 0.1 | |
| Carbohydrates | 3.02 | 47 |
| Protein | 7.2 | 8.7 |
| Fiber | 0.97 | 4.2 |
| Vitamin C | 5.97 | |
| Salt | 0.28 | 1.1 |
| | | Margarine |
| | | 2219 |
| | | 539 |
| | | 60 |
| | | 18 |
| | | <0.5 |
| | | g |
| | | g |
| | | g |
| | | g |
| | | mg |
| | | g |

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