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Noise and its impact on the perception of food and drink

Charles Spence

Abstract

Noise is currently the second most common complaint amongst restaurant-goers, behind poor service. In fact, over the last decade or two, many restaurants have become so loud that some critics now regularly report on the noise levels alongside the quality of the food. In this review, I first highlight the growing problem of noise in restaurants and bars and look at the possible causes. I then critically evaluate the laboratory-based research that has examined the effect of loud background noise on taste perception. I distinguish between the effect of noise on the taste, aroma/flavour, and textural properties of food and drink. Taken together, the evidence now clearly demonstrates that both background noise and loud music can impair our ability to taste food and drink. It would appear that noise selectively impairs the ability to detect tastes such as sweet and sour while leaving certain other taste and flavour experiences relatively unaffected. Possible neuroscientific explanations for such effects are outlined, and directions for future research highlighted. Finally, having identified the growing problem with noise in restaurants, I end by looking at some of the possible solutions and touch on the concept of silent dining.

Keywords: Flavour, Noise, Taste, Masking, Sensation transference

Review

Introduction

Restaurants are getting noisier. That, at least, is what the critics say. If the increase in noise levels is anything like as widespread as has been suggested in the media, then the question that we have to ask ourselves is why this should be so. According to some commentators, it is nothing more than the result of a decision by certain influential North American chefs to play the same music in the dining room that they were fond of listening to in the kitchen. However, other commentators see an ulterior motive here, linked to restaurateurs' attempts to increase their bottom line. As Buckley [1] puts it,"*....the Hard Rock Café had the practice down to a science, ever since its founders realized that by playing loud, fast music, patrons talked less, consumed more and left quickly, a technique documented in the International Directory of Company Histories.*"

Both laboratory-based research [2] and field studies [3,4] converge on the conclusion that people drink more when exposed to loud music[a]. So, for example, the participants in one laboratory study reported by McCarron and Tierney drank more of a soft drink, at a faster rate, when loud popular music was playing at 88 dB than when it was played at a more reasonable 72 dB instead [2]. Meanwhile, Guéguen et al. [4] conducted a more ecologically valid study in a couple of bars, one located in a rural area and the other in an urban environment in France. The volume of the popular music that was normally played in the bars was varied. The 120 customers whose behaviour was observed ordered significantly more to drink when the music was played at 88–91 dB than when it was played at its normal level of 72–75 dB. Thus, there is good reason to believe that there might be a direct link between the loudness of the background music and the increased profitability for the owners of those establishments that choose to play loud music.

Similar results were reported in another study from the same group of researchers (see Table 1). In this study, the behaviour of 40 pairs of young male drinkers aged between 18 and 25 years in two French bars was monitored. One of the bars had normal music levels (72 dB), whereas the other venue played their music at a much louder level (88 dB). The patrons drank significantly faster, and, what

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Table 1 Number of drinks and time taken to consume a drink in an observational study conducted in two French bars by Guéguen et al. [3]

Noise level	Number of drinks consumed	Time taken to finish drink (min)
Normal (72 dB)	2.6	14.5
High (88 dB)	3.4	11.5

is more, ended up consuming significantly more overall as the loudness of the music was turned up [3]. Given such results, it is probably no coincidence, then, that many pub and bar owners prefer louder music.

At this point, it is worth noting that we are not the only ones who show such noise-induced behaviours. Even lab rats eat and drink more as the background noise level goes up. Kupferman [5] who conducted this particular study speculated that the increase in eating and drinking (that was sometimes observed even when the animals were already full) could be explained in terms of a stress response—a kind of displacement activity if you will [6]. The idea was that this would help to distract the animals from the environmental stress associated with being subjected to 80 dB of noise (see also [7]). Intriguingly, recent findings from a 4-year study from the Karolinska Institute in Sweden found that for every 10-dB increase in the road traffic noise levels, there was a 3-cm increase in waist size. More dramatically still, those exposed to loud airplane noise had a waist line that was, on average, 6 cm larger [8].

A growing number of restaurateurs and bar owners have come to the realization that they can increase their turnover simply by turning up the background music—as the volume goes up, people drink more. However, perhaps unsurprisingly, not everyone is happy about this sonic overstimulation. According to the results of a recent Zagat Survey, when restaurant-goers were asked "*What irritates you most about dining out?*", "noise" was highlighted as the second most common complaint, behind poor service [9] (see also [10,11])[b].

There is, of course, a separate question here as to why exactly pumping up the volume should increase consumption. As we will see below, one possibility is that loud noise changes the taste/flavour of a drink. Perhaps more importantly though, it may also make it harder for the consumer to discriminate the alcohol content of whatever happens to be in their glass [12]. Alternatively, however, it may be that with loud 'foreground' music, the drinkers in these studies were simply unable to hear what the people they were with were saying [13]. Follow-up studies in naturalistic environments where the drinking behaviour of both solitary patrons and groups of drinkers is monitored would certainly help to discriminate between these possibilities.

It is not altogether clear though just how many chefs think of these noise levels as being particularly problematic. Just take the following quote from chef Ryan Poli of the Tavernita restaurant in Chicago, "*I think it's totally wrong to think you can't have a great restaurant that's also pretty damn loud.*" (quoted in [14]). Or the following from Melbourne restaurateur Chris Lucas, "*It has been pointed out to me I have a penchant for noisy restaurants*." Lucas, owner of city hot spots Chin Chin and Go Go Bar and the Italian eatery Baby I Richmond, says, "*You can't have fun without noise. When we set out to replicate the buzz of a Thai street market with Chin Chin, we did it carefully. I don't like four empty walls with no buzz.*" (quoted in [10]). Many chefs and restaurateurs appear to see noise as just another element in the creation of a successful restaurant concept.

However, as drinkers and diners, are we really happy to let the noise levels continue to rise? The situation can certainly appear very different from the perspective of those whose ears are being assailed by the often thunderously loud music: As we will see below, the latest evidence now demonstrates that background noise really can impair our ability to smell, taste, and enjoy the flavour of food and drink. It can thus be argued that tackling the problem of overly noisy restaurants and bars is becoming a more pressing issue than ever before when it comes to enhancing our perception of food and drink.

But first, it is important to pause for a moment to think about what exactly noise is. Well, noise has been defined as "*a sound, especially one that is loud or unpleasant or that causes disturbance*"[c]. In the setting of science laboratories, researchers tend to present either narrowband or broadband white noise to their participants in order to study the influence of what people hear on what they taste. Out there in the real world, though, noise comes in many forms: everything from the sound of aircraft engines when we eat in the skies (see [15]) through to the unpleasantly loud background noise that one finds at many a restaurant on a busy evening. Opinions on the matter differ, of course, and one person's preferred background music can legitimately be considered as another's unpleasant racket (see also [16], p. 6 and [17]). However, that said, what is clear is that it is no longer just the old and hard-of-hearing who are finding the noise levels in many of our public spaces too loud nowadays [11].

Interestingly, while a number of the earliest laboratory studies failed to detect any discernible effect of the presence of background noise on taste and flavour perception [18-20], many of the more recent studies in this area now converge on the conclusion that loud noise really can exert a significant (and often negative) effect on people's perception and enjoyment of whatever it is that they happen to be eating [21] or drinking [12]. This intuition was captured by one writer some years back, "*A loud noise, for instance, may prevent entirely our ability to smell or taste, yet softly played dinner music can create an environment*

favourable for elegant dining." ([22], p. 7). And although, as we will see below, the precise causes of such effects of noise on our taste perception have yet to be thoroughly worked out, a number of plausible hypotheses have been put forward in the literature over the years.

In the sections that follow, we will start by looking at the growing hubbub surrounding many restaurant diners nowadays. Next, the various laboratory-based studies that have addressed the question of whether background noise actually affects people's experience of the various aspects of taste, aroma, food texture, and flavour perception will be reviewed. Ultimately, I hope to convince you of just how much of a problem background noise really is when it comes to trying to enjoy food and drink. Some of the solutions that are currently available are then highlighted. Finally, we will take a look at the latest silent dining experiences that are now starting to pop up and which can offer diners a brief respite from all that noise.

Restaurant noise

Have you ever found yourself in a restaurant that is simply too loud? So loud that you find yourself glued to your companion's lips just to catch a smattering of what they are trying to say. If so, you would join the growing number of customers who, in the last few years, have started to complain about those restaurants and bars where one simply cannot hear oneself think, never mind listen to what the person sitting across the table from you might be saying ([1,11,16,23], p. 6, [17,24-29]). As Cornish [10] puts it, "*You go to restaurants to be social. These days, you often come out none the wiser of what the other person has said.*" No matter where you happen to live, you can probably point to a diner that has been spoiled by the overpowering background, or should that be foreground, noise.

The problem is such that over the last decade or so, a growing band of increasingly vocal North American restaurant critics has started to complain that the background noise levels in many restaurants are simply too high. They are so loud, in fact, that they can no longer taste/enjoy their food (e.g. see [11,26,28]). In 2008, Sietsema recorded the noise levels in a number of North American restaurants at 90 dB at especially busy times. And, in 2012, Cara Buckley, writing for *The New York Times*, recorded sound levels averaging 94–102 dB at restaurants such as Lavo in Midtown Manhattan, the Brooklyn Star in Williamsburg, the Standard Hotel's Biergarten in the meatpacking district, and Beaumarchais on West 13th Street [1].

But when exactly did the problem with restaurants that are too loud start? Is it something that has always been with us, or is it rather just a sign that those who are complaining have reached middle age, the time at which one becomes rather less tolerant of ambient noise as one's hearing starts its inevitable decline? Some writers have suggested that the problem with rising noise levels can be traced back to the mid-1990s [27], in particular, to the occasion when the chef Mario Batali first decided that it would be a good idea to blast out the same music in his restaurant Babbo that he liked to listen to in the kitchens (Zeppelin, the Who, the Pixies, etc.) while preparing his signature Italian cuisine[d]. Subsequently, other chefs, such as David Chang apparently followed in Batali's footsteps. The result? The wall of sound that many of us now face while dining out.

That said, it is important to remember here that the perceived noise level in a public space such as a restaurant depends not only on the amount of sound generated by those who are occupying the space (and any music that happens to be being pumped out from the loudspeakers) but also on the reflectance properties of the various surfaces and soft furnishings, should there be any. Some commentators have suggested that the Scandinavian or industrial feel that has become so popular in many restaurants and bars in recent years [30] is partly to blame. All that bare wood, and all those stripped down surfaces, etc. might just be contributing to the elevation in background noise levels that so many of us are now complaining about [1,11,26]. Just take restaurant critic Paul Reidinger's description of the acoustics in San Francisco's Delfina restaurant, "*Spare walls, stone floors, and shiny, cold zinc-topped tables amounting to an ideal environment for the propagation of decibels… a crescendo that's not unlike the approach of a train. All that's missing is a horn and a flashing light.*" (cited in [29], p. 118]).

> "*Many of the most cutting-edge, design conscious restaurants are introducing a new level of noise to today's already voluble restaurant scene. The new noisemakers: Restaurants housed in cavernous spaces with wood floors, linen-free tables, high ceilings and lots of windows—all of which cause sound to ricochet around what are essentially hard-surfaced echo chambers.*
>
> *Upscale restaurants have done away with carpeting, heavy curtains, tablecloths, and plush banquettes gradually over the decade, and then at a faster pace during the recession, saying such touches telegraph a fine-dining message out of sync with today's cost-conscious, informal diner. Those features, though, were also sound absorbing.*" [26].

According to Lang [31], the first regular inclusion of noise ratings in restaurant reviews was back in 1990 when the *San Francisco Chronicle* included "sound level" as one of the categories in its summary review tables.

The New York Times started to do the same in 1998. In April 2008, the US food critic Sietsema, who formerly wrote for *The Village Voice* and subsequently for *Eater* [27], started to include noise ratings alongside all the other information that one would normally expect to find in his restaurant reviews [11,28]. Sietsema's restaurant noise rating system is as follows:

- *Quiet* (under 60 dB)
- *Conversation is easy* (60–70 dB)
- *Must speak with raised voice* (71–80 dB)
- *Extremely loud* (over 80 dB)

To put these values into some kind of perspective, Sietsema provides the following helpful pointers: 50 dB is the sound of a moderate rain shower, 60 dB equates to normal conversation, 70 dB is equivalent to the noise made by a loud vacuum cleaner, and noise levels greater than 80 dB (think city traffic) are apparently potentially hazardous to hearing if one is exposed to them for a sustained period of time—if not for the diners themselves, then definitely for the restaurant and bar staff [1,8,32]. Here, it is important to note that every 10-dB increase in background noise is subjectively perceived as a doubling in loudness. Hence, a restaurant at 80 dB will be twice as loud as a restaurant where the noise level is recorded at just 70 dB.

Interim summary

Summarizing what we have seen so far, there seems to be mounting evidence that many restaurants are becoming louder. This would appear to be the result of restaurateurs and bar owners trying to increase their bottom line by turning the music up (since people drink, and hence spend, more in louder environments). It may, however, also reflect the changing design aesthetic in many contemporary restaurants, with more sound-reflecting and fewer sound-absorbing surfaces and furnishings. Whatever the cause(s) and motivation(s), what is becoming increasingly clear is that a growing number of people these days find that the noise levels have got unpleasantly loud. And there is every sign that what may once have been primarily a US problem [33] is spreading to many other westernized countries [10,34]. However, beyond the impact of loud background noise on our enjoyment of the overall experience of dining out, one can ask what impact it has on our ability to taste and enjoy the flavour of that which we are eating and drinking?

Studying the impact of noise in the laboratory

A little over half a century ago, Pettit [20] conducted one of the first, not to mention one of the only, studies to look specifically at the effect of loud restaurant noise on people's preference judgments. A panel of 84 untrained male and female college students evaluated a selection of three tomato juices made up of a reference sample and two comparison samples. The juices were tasted in one of three different locations while pre-recorded restaurant noise was sometimes played in the background at 80 ± 5 dB. As Pettit ([20], p. 56) describes it, "*Sounds emanating from the tape were the intermixture of clattering dishes and utensils, scuffing and scraping, voices, and background noises.*" Neither the presence of background noise nor the location in which the tomato juices were evaluated had any impact on people's preference judgments. However, that said, given the design of Pettit's study, it is impossible to know whether or not the noise affected people's overall hedonic ratings, or whether it affected the more sensory-discriminative aspects of taste perception.

Assessing the impact of background noise on taste (gustatory) perception

McFadden et al. [19] conducted some of the earliest psychophysical research on the impact of noise on taste perception. The participants in this study tasted a series of salty or sweet solutions (sodium chloride and sucrose in distilled water, respectively) at various concentrations while sometimes listening to narrowband noise (in the 100–3,000-Hz range) presented at 70-dB SPL (though at 104 dB within the stimulated frequency range). In the first experiment, sweet and salty stimuli were presented at close to threshold levels while the participants tried to ascertain whether or not the tastant was present in the solution. In the second study, a magnitude estimation procedure with suprathreshold taste solutions was used instead. However, despite the differing experimental designs, no evidence was obtained to support the claim that background noise suppressed the participants' ability to taste in either study (see Figure 1). That said, it should be remembered that only a small number of participants were tested—four in one experiment and six in the other[e]. What is more, the participants were only ever asked to rate the sensory-discriminative qualities of the gustatory stimuli; that is, they were never asked about the hedonic qualities of the tastants, namely, how much they liked them.

A few years later, however, Ferber and Cabanac [35] conducted a study in which the hedonic valence of sucrose (but not of sodium chloride) solutions were elevated (meaning that people reported liking the solutions more) when listening to either loud noise or music. The ten male participants who agreed to take part in this experiment had to start listening to the auditory stimuli 20 min prior to tasting to, in some sense, match the conditions that one might expect to find in a restaurant or cafeteria when dining. The sweet solutions were rated as significantly

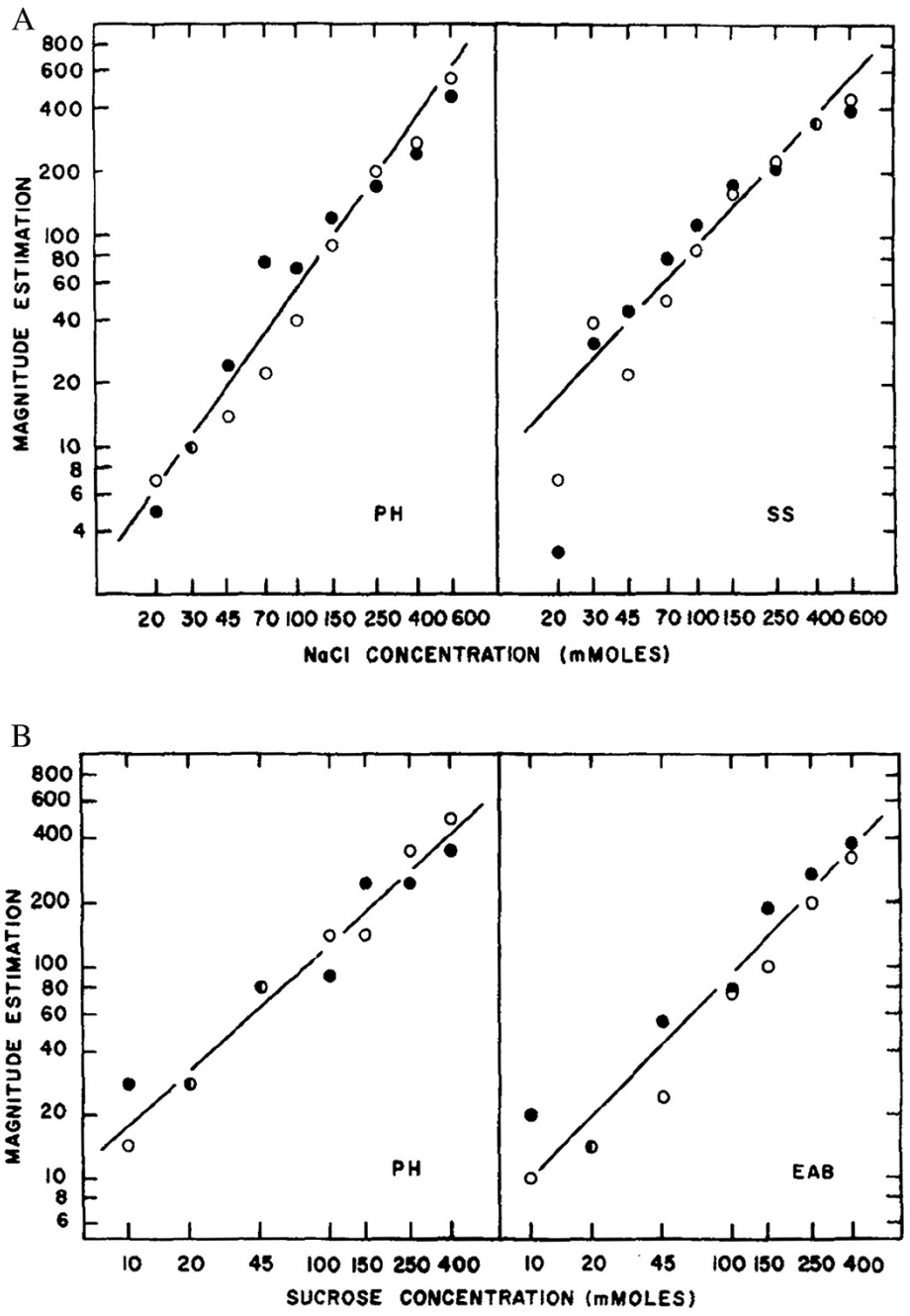

Figure 1 (A & B) Four graphs showing the results of individual participants in McFadden et al.'s [19] magnitude estimation study on suprathreshold salty and sweet solutions made in the absence (*white circles*) versus presence (*black circles*) of background noise. Visual inspection of these graphs clearly reveals that the presence of the background noise had no obvious impact on this participant's sensory-discriminative ratings of the perceived intensity of the tastant. Source: [19].

more pleasant when the participants were in the presence of the loud background noise or music (both presented at 90 dB over headphones) than when tasting in silence or while listening to quiet music (70 dB) instead (see Figure 2). Interestingly, despite the fact that each person was allowed to listen to the music that they liked (that is, they were encouraged to bring their own preferred music into the study), it was the presumably unpleasant white noise that actually gave rise to the largest sweetness enhancement effects. Ferber and Cabanac [35] suggested that this particular crossmodal effect may have been mediated indirectly via the modulatory influence of noise on participants' arousal/stress levels which, in turn, may have affected their taste perception.

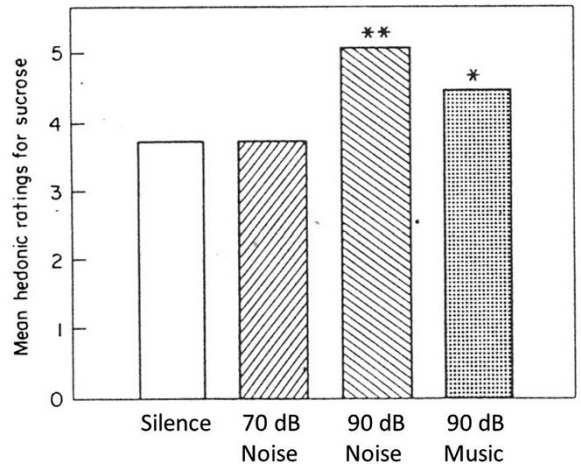

Figure 2 Mean ratings of the "pleasure" evolved by sucrose stimuli in Ferber and Cabanac's study [35]. *Asterisks* compared to the control group (*white*) are all $p < 0.05$. Source: [35].

More recently, Woods et al. [21] conducted two laboratory-based experiments designed to assess the impact of presenting loud versus quiet background noise (75–85 dB vs. 45–55 dB, respectively) over headphones on the perception of the sweetness, sourness, and liking of a variety of foodstuffs. In this study, a repeated measures design was used with participants rating Pringles potato chips, cheese, biscuits/crackers, and flapjack on a number of Labelled Magnitude Scales. The 48 participants in the first experiment of Woods et al.'s study rated salty foods (crisps and cheese) as significantly less salty and sweet foods (biscuits and flapjack) as tasting less sweet under conditions of loud background noise (see Figure 3A). By contrast, there was no such effect on the participants' liking (i.e. hedonic) ratings. These results therefore highlight the significant effect that loud noise can have on the sensory-discriminative aspects of taste perception.

In 2012, however, Stafford et al. [12] seemingly obtained the opposite pattern of results in a study in which 80 people rated alcoholic beverages as tasting sweeter when listening to loud background music (comprising drum and bass, house, hardcore, dubstep and trance) than in the absence of any background music (see Figure 4). Why inconsistent results should have been obtained in the latter two studies is, at present, unclear. That said, differences in the experimental stimuli used (food vs. drink) and in the kind of auditory accompaniment that the participants heard (noise vs. trance music) should certainly be borne in mind here. Follow-up studies are undoubtedly warranted in order to determine when exactly loud noise suppresses the perception of sweetness and when instead it enhances it.

One potentially confounding factor that is worth bearing in mind here though relates to the fact that basic tastes often mutually suppress one another. So, for example, adding a small amount of salt to a glass of tonic water will make it taste sweeter. Why so? Well, because the salt suppresses the bitterness and hence releases the sweetness ([36], see also [37,38]). Complicating matters still further in this regard, odours are also known to suppress, or enhance, the perception of taste [39,40]. Hence, it would seem possible that when evaluating a complex taste/flavour mixture, noise might suppress one taste, which, in turn, might lead to the unmasking of another. Such an indirect effect of noise need not be present when the latter tastant is presented in isolation (e.g. as in Ferber and Cabanac's study [35]). Another intriguing result to emerge from the recent research of Stafford et al. [12] was that combining loud background music with a secondary shadowing task (designed to mimic a person trying to have a conversation in a noisy bar) impaired their participants' ability to correctly judge the alcohol content of the drinks that they were tasting. Next, we will take a look at how background noise affects the perception of the textural aspects of food.

Assessing the effect of background noise on judgments of the texture of food

In recent years, there has been growing interest in the role that auditory cues (specifically food-related mastication sounds) play in the perception and enjoyment of food and drink (e.g. see [41-43] for reviews). As Crocker ([22], p. 7) put it more than half a century ago, "*The act of eating may produce characteristic sounds, such as the crunching that goes with biting into an apple or eating a stalk of celery, the snap that goes with breaking crackers or Melba toast, and even the silence that goes with indulgence in whipped cream.*" Food-related sounds include everything from the crunch or crack of dry food products such as potato chips, biscuits, and many breakfast cereals [44-46] through to the sound of carbonation in a sparkling drink (see [47], p. 93, [48,49]).

Once again, the early research in this area does not make for particularly inspiring reading (at least for those interested in crossmodal research): For instance, Christensen and Vickers [18] investigated the effect of presenting 100 dB of radio static over headphones on participants' judgments of the crispness of 16 dry and wet crisp products (e.g. celery, turnip, radish, ginger snap, rye krisp, and the curiously named Triscuit) as estimated by the Magnitude Estimation procedure. Despite the fact that 12 of the 16 food samples received higher crispness ratings when the loud background noise was presented and despite the fact that 70% of the participants gave higher crispness ratings when their food mastication sounds were blocked with noise, no significant main effect of the auditory manipulation was observed on participants' food ratings[f]. Christensen and Vickers also failed to find any effect of

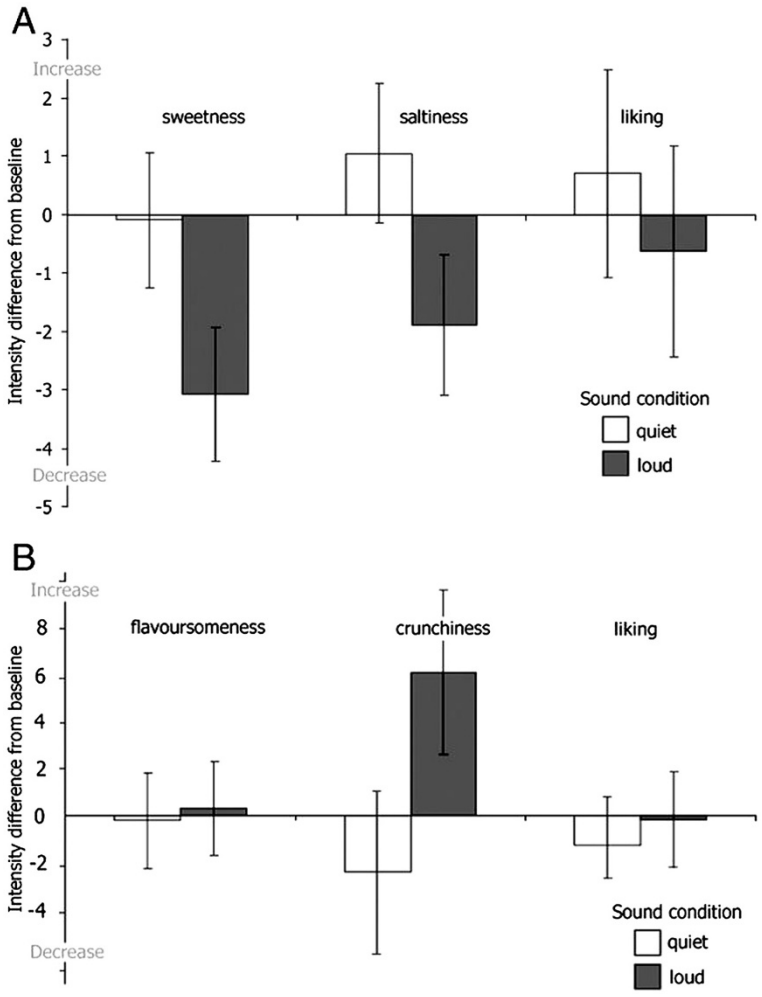

Figure 3 Effects of quiet and loud background noise on sugar, salt, flavoursomeness, crunchiness, and liking. (A) The effect of background noise levels on sugar, salt, and liking intensity ratings in Wood et al. [21]. Experiment 1, relative to the baseline condition; a negative value indicates a lower level than the baseline and a positive value a higher level. *Error bars* = 2 SEM. **(B)** The effect of quiet and loud background sounds on flavoursomeness, crunchiness, and liking intensity ratings reported in Experiment 2, relative to the baseline condition. Source: [21].

the same manipulation of the background noise on people's rating of the perceived viscosity of various liquids thickened by means of the addition of sodium alginate.

More recently, though, a number of researchers have reported significant effects of loud background noise on the perception of various noisy food products. So, for example, the participants in one study by Masuda et al. [50] found it harder to discern the moistness of a moist pretzel when the mastication sounds that were generated while eating were masked by loud white noise presented over headphones (at 82 dB). Interestingly, though, no such effects were reported when dry pretzels were evaluated instead. Meanwhile, Woods et al. [21] had the 34 participants in their second experiment rate flavoured rice cakes (salt and vinegar, berry and caramel, marmite, etc.) in terms of their crunchiness, overall flavour, and liking. This noisy foodstuff was judged to be much crunchier when loud background noise was played (see Figure 3B). Once again, though, the noise had no effect on how much the participants liked the foods nor how flavourful they found them. It may be relevant here to note in passing that auditory masking has also been shown to influence the neuromuscular control of chewing [51,52].

Assessing the effect of background noise on aroma/flavour judgments

It has been estimated, at least by some researchers (e.g. see [53,54]), that as much as 80% or 90% of what people commonly refer to as the taste of food and drink really originates from the olfactory signals picked up by the nose (rather than by the taste buds on the tongue). Given such a figure, it would certainly make sense to try and understand the extent to which loud background noise

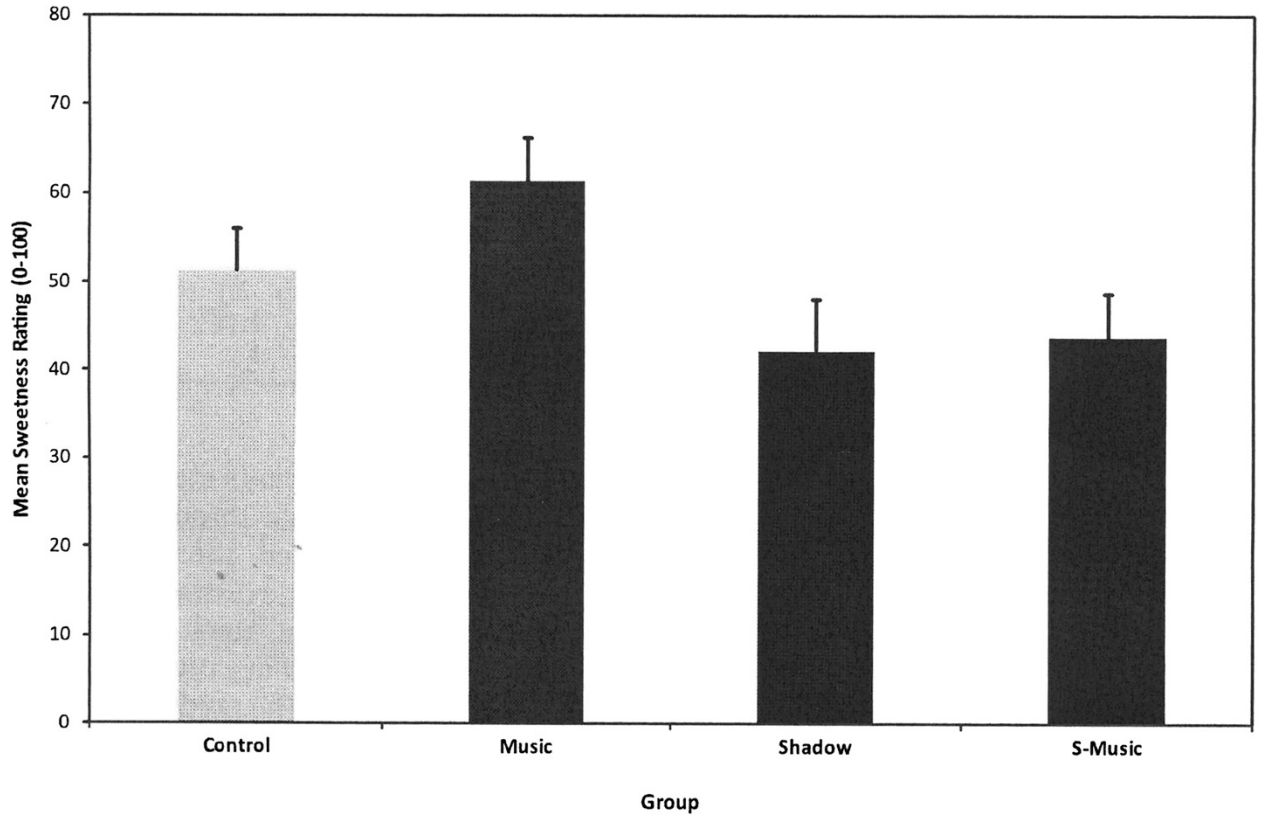

Figure 4 Mean sweetness ratings by group in a study of noise on the perception of alcoholic drinks by Stafford et al. [12]. *Error bars* represent standard errors of the mean. Source: [12].

affects the perception of food-related odours, since this might *a priori* be expected to have the largest overall effect on people's flavour perception. One study that has actually tackled this very question was reported by Seo et al. [55]. These researchers played various kinds of background noise over headphones while their participants' performed an odour discrimination task. People were handed triplets of "Sniffin' sticks", essentially smelly felt-tip pens, of which two had the same odour, and one was different. The participants had to try and pick the odd one out. Verbal noise, in this case someone reading an audio book at 70 dB, was found to exert a more detrimental effect on performance than party noise presented at the same level, which, in turn, was more detrimental than silence (see Figure 5). By contrast, listening to Mozart's sonata for two pianos in D major K448 did not affect performance relative to a silent baseline condition.

In a follow-up study, Seo et al. [56] went on to demonstrate that performance on an odour sensitivity task was unaffected by the presence of background noise (again either verbal or non-verbal) when compared to a baseline silent condition. However, that said, in this case, a closer look at the data revealed that this null result hid some potentially interesting individual differences: In

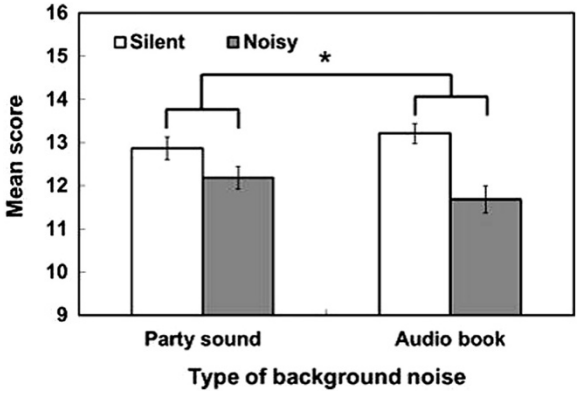

Figure 5 Comparison of the mean scores in the odour discrimination task in the "silent" and "noisy" conditions from a study reported by Seo et al. ([55], Experiment 1]). Compared with the silent condition, the mean score in the odour discrimination task was significantly lower in the presence of background noise (e.g. "party sound" or "someone reading an audio book"). In addition, comparing the difference between the mean scores in the silent and noisy conditions in relation to the type of background noise, the mean difference in scores in the audio book session was significantly higher than that in the party sound condition. *Significance at $p < 0.05$. The *error bars* represent the standard errors of the means. Source: [55], Figure one.

particular, while verbal background noise significantly impaired the olfactory sensitivity of those participants who had been categorized as introverts, it had the opposite effect on the more extroverted participants (personality in this case being assessed by means of a questionnaire). These results therefore demonstrate—for possibly the first time—an individual differences angle to the question of how background noise influences chemosensory perception.

In our own research ([57] see also [58]), we exposed a group of participants to six different food-related odours (lemon, orange, bilberry, musk, dark chocolate, and smoked) while either listening to music or white noise (once again presented over headphones at 70 dB). The olfactory stimuli were rated as significantly less pleasant (by around 5 points on a 100-point visual analog scale) in the presence of white noise than when either pleasant or unpleasant (consonant and dissonant) musical selections were played instead. These results contrast with the positive effect of white noise on ratings of the pleasantness of sucrose solutions reported by Ferber and Cabanac [35]. One suggestion that emerges from the contrast between these two sets of results is that noise might have a somewhat different effect on olfactory, as compared to gustatory, perception. However, that said, it should also be noted that the very intense stimuli utilized in Ferber and Cabanac's study, together with the inverted U-shape pleasantness function that is seen as a function of sweetness intensity, means that the effect of noise (either positive or negative) might depend as much on where on the U-shaped pleasantness function a particular stimulus falls, as on the particular sensory modality that happens to be being stimulated.

Interim summary

A growing body of laboratory-based research now demonstrates that loud background noise can affect the ability to taste food (see Table 2 for a summary of the research published to date). More specifically, both taste and smell (or aroma) can be affected, as are people's ratings of the perceived texture of a variety of dry food products. While sensory-discriminative judgments of intensity or of the presence vs. absence of a particular taste, aroma, or flavour seem to be impaired, crunchiness has, on occasion, been boosted by the presence of loud background noise. Generally speaking, though, the ability of people to discriminate between similar taste, aroma, or flavour stimuli would appear to be impaired (that is, their sensitivity is lowered). Meanwhile, in terms of hedonic judgments, the available research supports the somewhat counterintuitive claim that while unpleasant loud noise enhances the pleasantness of certain tastants [35], it has either no effect or else a suppressive effect on hedonic ratings for other food-related stimuli [58]. Ultimately, though, it has to be admitted that the literature in this area is complicated by the fact that not all studies have documented an effect of noise on taste, flavour, and/or texture perception (see [18-20] for null results). Furthermore, as we have just seen, background noise appears to have somewhat idiosyncratic effects on the different attributes of taste/flavour.

Why does background noise affect taste perception?

Having demonstrated that what we hear can affect the taste and flavour of food and drink, the obvious next question is why this should be so. Here, it may be important to discriminate between the effect of noise on the sensory-discriminative attributes of food or drink (what is the identity of the taste/flavour and how intense is it) and its influence on the more hedonic aspects of taste/flavour perception (how much a person likes the overall experience). To date, several different hypotheses have been put forward, and it is to these explanations that we turn next.

The attention/distraction account One possible explanation as to why the presence of noise should influence taste perception is simply that it distracts a person's attention from whatever it is that they happen to be tasting/eating [59]. This idea was hinted at some years ago by the famous French wine expert Emile Peynaud when he stated that "*The sense of hearing can interfere with the other senses during tasting and quiet has always been considered necessary for a taster's concentration. Without insisting on absolute silence, difficult to obtain within a group in any case, one should avoid too high a level of background noise as well as occasional noises which can divert the taster's attention.*" ([60], p. 104). Distraction might be expected to impact both sensory-discriminative and hedonic judgments [61-63].

The beginnings of a neural account of how distracting noise (noise that captures a diner's or drinker's attention) might influence ratings of the olfactory attributes of flavour come from the results of a neuroimaging study by Plailly et al. [64]. These researchers found that when people concentrated on their sense of smell, as opposed to directing their attention toward hearing instead, there was a noticeable increase in the neural connectivity between the piriform cortex (the primary olfactory cortex) and the orbitofrontal cortex (a small part of the brain lying between the eyes and set back a little bit that is a multisensory integration site and decision-making centre that codes for the reward value of stimuli [45,65]) via the thalamus (an early neural relay site). By contrast, connectivity in this (indirect) route between the piriform and orbitofrontal cortex was reduced when the participants concentrated on what they were hearing instead. Hence, the suggestion here is that the influence of noise on the

Table 2 Summary of the results of those studies that have investigated the impact of noise on taste/flavour perception

Study	Noise presentation	Number of participants	Noise level (and type)	Foodstuff	Method	Results
Pettit [20]	External	84	80 ± 5 dB (restaurant noise)	Tomato juice	Preference judgments amongst three juice samples	No effect of noise on preference judgments
McFadden et al. [19]	Headphones	4	70 dB (narrowband noise)	Sweet and salty solutions	Threshold psychophysics	No effect of noise on threshold or suprathreshold intensity judgments
		6			Magnitude estimation	
Christensen and Vickers [18]	Headphones	16	100 dB (radio static)	16 wet and dry foods	Magnitude estimation	No significant effect of noise
				Viscous liquids	Magnitude estimation	No effect of noise
Ferber and Cabanac [35]	Headphones	10	70/90 dB (noise)	Sweet and salty solutions	Magnitude estimation	Significant effect of loud noise and music on hedonic responses to sweet (but not salty) solutions
			90 dB (music)			
Masuda et al. [50]	Headphones	7	82 dB (noise)	Moist and dry pretzels	Two-alternative forced choice	Significant effect on ratings of moist (but not dry) pretzels
Woods et al. [21]	Headphones	48	75–85 dB (noise)	Pringles/cheese	LMS	Sweetness & saltiness ratings significant
			45–55 dB (noise)	Biscuit/flapjack	LMS	Lower with loud noise, liking ratings not significant
Woods et al. [21]	Headphones	34	75–85 dB (noise)	Flavoured rice cakes	LMS	Crunchiness ratings higher with loud noise
			45–55 dB (noise)			Flavour and liking ratings not significant
Seo et al. [55]	Headphones	38	70/82 dB (verbal or party noise)	Odorants	Triangle test	Verbal noise > effect than party noise > quiet; odour discrimination worse
Stafford et al. [12]	Headphones	80	Noise	Alcoholic drinks	Visual analogue scales	Alcoholic beverages rated significantly sweeter
			Noise and shadowing	Alcoholic drinks	Visual analogue scales	Worse discrimination of alcohol content
Seo et al. [56]	Headphones	39	Verbal noise	Odorants	Triangle test	Introverts' performance significantly worse, extroverts' performance significantly better

olfactory attributes of flavour perception may operate by changing the connectivity between those parts of the brain that are involved in transmitting the information concerning the olfactory stimulus through the various relevant brain structures.

It is also interesting to consider whether the direct connections between the ear and the olfactory system (specifically the olfactory tubercle located in the basal forebrain), a neural pathway that was only discovered a few years ago [66], might not also play some role. This accidental discovery came after Wesson noted that the tubercle, whose olfactory responses he was studying, responded (i.e. there was a spike of neural activity) whenever someone put their coffee mug down on the lab bench [67]. It turns out that approximately 20% of the units that the neurophysiologists recorded from were driven by the presentation of a tone at 76 dBA. Although the exact function of such newly discovered cross-sensory neural connections in the mouse model has not, as yet, been fully worked out, it would not seem beyond the realms of possibility to suggest that they might play at least some role in the influencing of a person's aroma/flavour judgments whenever a person is exposed to loud noise.

The masking account Another possible explanation here for why background noise influences taste/flavour is simply that it suppresses (or masks) the auditory (and possibly also oral somatosensory) cues that are normally heard when we eat various crisp and crunchy products, not to mention constituting a good part of our enjoyment of carbonated beverages [21,42,45,46,48,49]. Psychologists typically think of masking as a low-level sensory effect. That said, the empirical evidence does not appear to provide any straightforward support for such an account. In particular, one would have expected that the presentation of loud noise would, if anything, have suppressed the perception of crunchiness/crispness (i.e. auditory dominant food attributes). As it turns out, however, the opposite result has been observed ([18,21] also reported a similar trend in their data). Beyond any direct suppression of food sounds by background noise, one might also wonder about the possibility of there being cross-sensory (or crossmodal) masking from sound on taste or smell (cf. [68]; though see also [19]). It should, though, be acknowledged that not all researchers even believe in the possibility of crossmodal masking. Here, it is perhaps also worth noting that while the attention/distraction and masking accounts are typically treated separately in the scientific literature,[g] it may not prove so easy to distinguish between them in the present case.

The arousal/alerting account A third suggestion that has been mooted by some authors over the years is that exposure to loud noise elicits a stress/anxiety response and hence may put people in a worse mood than would otherwise have been the case. The claim is that this, in turn, depresses hedonic responses to the taste and flavour of food and drink (cf. [5,21,35,69]). A related notion here is that the presence of loud music leads to a heightened state of arousal which somehow modifies the way in which a diner/drinker experiences and/or responds to tastes and flavours [3]. These two explanations are linked inasmuchas the cause of the crossmodal effect of noise on taste/flavour is attributed to a change in the general state of the observer. However, I would argue that while it is most certainly true that our mood affects our perception of food (see [70] for a review), the arousal/alerting account has not really been sufficiently well-worked out over the years by its proponents to have generated testable, and tested, predictions. That said, this kind of account is perhaps the only one that straightforwardly predicts that loud background noise would have a somewhat different effect on the hedonically pleasant taste of sweetness than on the other tastes.

The sensation transference account Finally, noise—no matter whether it be white noise or just very loud and hence unpleasant music—could potentially influence people's ratings of the taste and smell of food by means of sensation transference or halo/horn dumping [71-74]. According to this suggestion, what a person feels about a given source of background noise (i.e. whether they like it or not) may carry over to influence their perception (or rating) of any food or drink tasted while listening to that noise. Certainly, the literature is replete with examples of sensation transference from all manner of product extrinsic cues [75]. Furthermore, there have been several specific examples of people's feelings about the background music being shown to carry over to colour their judgments of a variety of other unrelated situational attributes.

In one study, for instance, people's ratings of the environment were affected by the music that was playing in the background [74]. This crossmodal effect was especially noticeable when the perceived attributes of the music and environment failed to match up. Meanwhile, in another recent study, ratings of the pleasantness of gelati were significantly higher when people listened to their preferred music than when they listened to music that they did not like [76]. With respect to the arousal/alerting explanation mentioned above, it should be noted here that sensation transference effects can presumably occur in the absence of any change in the mood (or general internal state) of the observer. However, that said, Ferber and Cabanac's [35] early finding that listening to unpleasant white noise elicited significantly higher hedonic ratings of sweetness than pleasant music stands

out as one salient finding that would seem to run counter to the predictions of the sensation transference account. The evidence that is currently missing from many studies in this area and that would undoubtedly help to provide a fuller assessment of the explanatory power of the sensation transference account are simultaneous ratings of what the participants feel about the background noise and also whatever they were eating or drinking, in order to see whether these ratings were correlated (cf. [21,77] for a recent move in this direction). Positively correlated ratings would provide further support for the sensation transference account. Now while the majority of the literature focuses on the idea that it is sensations that are transferred from an irrelevant attribute to the one that is being judged, perhaps the additional possibility should also be entertained at this point. Namely, that that what is transferred is not the sensation itself but rather the decision about that stimulus (e.g. as in the case of a decision as to whether or not we like the irrelevant stimulus attribute).

At present, then, it should be clear that no one theory can account for all of the findings that have been published in the literature on noise and its impact on taste and flavour perception. It will be the job of future research to try to determine just how much explanatory power each of the various explanations described above has when it comes to trying to account for the changes in the sensory-discriminative and hedonic responses to taste and flavour out there in the real world and not just in the setting of a science lab.

Does it matter how noise is presented?

Finally, one question to which we do not yet have a satisfactory answer is whether presenting noise over headphones, by far the most common situation in the laboratory research that has been conducted to date (see Table 2 for a summary), may have a different effect than when the sounds emanate from the environment (no matter whether that noise happens to be presented from loudspeakers or not). The latter situation is obviously much more ecologically valid when it comes to thinking about the real-world problems of excessive noise in restaurants that were documented earlier. Relevant here are those findings suggesting that, on occasion, people sometimes respond differently as a function of whether auditory stimuli are presented over headphones versus from external loudspeakers [78]. Nevertheless, should the results of the primarily headphones-based studies reported here be found to extend to the situation when the noise is environmental, then they become all the more important in the context of the growing number of complaints about restaurants that are overly noisy [9,11]. In fact, as we saw earlier, noise is currently one of the most common complaints highlighted by surveys of restaurant goers. What is more, direct comparison suggests that the noise levels in some restaurants now exceed those assessed in the majority of the laboratory-based research studies that have been published to date[h].

Interim summary

In conclusion, despite the publication of a number of early null results [18-20], I would argue that nowadays, there can be little doubt but that loud background noise affects our perception and enjoyment of food and drink, normally in an adverse manner (see [15,21,42])[i]. That said, sometimes, ratings of stimulus intensity (e.g. of crunchiness) actually go up in the presence of background noise [21]. Interestingly, the brain scientists have now started to provide neuroscience-based accounts that may potentially help explain why it is that what we hear in the background influences our response to what we taste [64,66]. As we saw in the last section, a variety of possible explanations have been put forward over the years, but further research is needed in order to more clearly discriminate between them. Furthermore, as we have just seen, it may also be appropriate to maintain a hint of caution when trying to extrapolate from the findings of laboratory-based studies to their real-world implications, given the use of headphones in so much of the research that has been published to date.

> "*Inside our dining rooms, one basic way we take care of our guests is by providing an atmosphere of comfort and welcome. Controlling noise and designing a thoughtful seating arrangement are effective tools to help us do that. I hear noise the way a good chef tastes salt: too much is overbearing; too little can be stifling. Guests are equally uncomfortable whether they have to shout to be heard or are required to speak in self-conscious, hushed tones in order not to have their conversation heard by other tables. With just the right noise level, each table has the luxury of becoming enveloped by its own invisible veil of privacy, allowing animated conversation to flow within that discreet container. Too much noise, on the other hand, aggressively invades the space and interferes with the guests' ability to engage with one another. It's annoying, stressful, and inhospitable.*" ([79], p. 246).

Solving the problem of noise in restaurants

Perhaps unsurprisingly, given what we have seen so far, tackling the problem of increasing noise levels is a growing concern for many restaurateurs. The most practical solution here is probably the increased use of efficient sound-absorbing materials, i.e. panels that are capable of reducing the background din. Companies like Acoustiblok sell QuietFiber to counteract just such problems. Similarly, Ecophon also offer purpose-designed sound

absorbing panels (http://www.ecophon.com/uk/; ([9,11,29], p. 119). According to McLaughlin [26], "*The best way to absorb reverberant noise is to cover at least two perpendicular surfaces with sound-absorbing material. If, for example, both the ceiling and one wall are treated with acoustical tiling, sound waves cannot bounce back and forth both horizontally and vertically.*" While such solutions certainly do not come cheap, [j] they will likely become increasingly important given that there is currently little sign that the growing number of complaints about background noise in restaurants and bars is going to die down anytime soon[k].

The restaurateur John Paluska has implemented another high-tech solution to combating the noise in his Mexican restaurant, Comal, in Berkeley, California. For, as well as utilizing sound-absorbing materials on the walls and ceilings (to create an 'acoustically dry' environment), this restaurant also incorporates an active auditory damping system. Twenty-eight microphones, situated over the heads of the guests, continuously sample the ambient noise in the restaurant. A digital processor then lengthens the sound and filters out all of those annoying high-pitched noises (such as the sound of forks hitting plates; [9]). The resulting sounds are then combined with music, amplified, and pumped back into the room via 95 speakers and sub-woofers mounted on the walls.

Diners at Paluska's restaurant experience a diffuse wash of background sound [9]. Crucially, what this high-tech solution allows the restaurateur to do is to separately modify the reverb near the bar and in the dining areas to adjust for occupancy levels and thus create a more exciting or relaxing atmosphere no matter where the guests happen to be congregating. The costs associated with implementing such a high-tech solution to noise management currently come in at anywhere from $10,000 to more than $100,000. Expensive, undoubtedly, but perhaps a worthwhile investment given that, as we have already seen, so much rides on a diner's sonic experience while in a restaurant. Certainly, this constitutes yet one more example of how technology can be used to rescue the dining experience through better management of the sonic environment (cf. [80]). And having said all that, should you find yourself in a particularly noisy restaurant where the latest in technology has yet to be installed or where there happens to be a chronic shortage of sound absorbing panels and soft furnishings, then the best advice is probably to make straight for any table situated in an alcove or side room, since these can help manage the noise levels [26].

Silent dining: future trend or passing fad?

Of course, just because noise is bad it does not mean that silence is necessarily golden. A restaurant or bar that is too quiet can easily lack that all-important attribute, "atmosphere" [70]. As Zagat, the founder of the dining guide, put it, "*It's a double-edged sword*," for if a restaurant is hushed "*a lot of people feel it's dead.*" (quoted in [11]). That said, as we saw earlier, wine experts sometimes advocate silence for their professional tastings [60]. Here, of course, it may simply be that the goals of the average diner and of the professional wine taster are really rather different. While the former presumably just wants to have the best overall experience, the latter wants to eliminate any external influence that might distract him or her from judging the qualities of whatever happens to be in their glass[l].

One might also think of those restaurants, such as Grant Achatz's Alinea in Chicago or Heston Blumenthal's The Fat Duck, in Bray, that have taken the deliberate decision not to play music in the background as a conscious policy to make sure that there is as little distraction from the experience of the food as possible [70]. While such temples to modernist cuisine [81] can likely withstand the unwavering focus of a diner's attention on the food/experience that is being delivered, it can certainly be a challenging policy to pull off effectively. Such was my feeling while dining recently at London's one Michelin starred W8. Indeed, one hears of far more restaurants that have failed because they lacked atmosphere than that are shut down for being too loud.

In terms of academic research on the effect of silence of taste perception, Srinivasan [82], in what is perhaps the very first published study to have looked at the interaction between sound and taste, attempted to remove all background noise by having 30 participants block their ears with their hands (either by sticking their fingers in or else by placing their palms against their ears) while tasting—though quite how the participants in this particular study managed to feed themselves while adopting this posture is not altogether clear. Anyway, however they did it, their perception of sweetness and saltiness of powdered cane sugar and common salt, respectively, was affected. Somewhat confusingly, though, while sweetness (and saltiness) was enhanced in some individuals, it was depressed in others. Hence, looking back now, it is difficult to know whether or not there was any clear overall pattern to the results of this early study[m].

In my own public engagement with science work, I have sometimes had those people seated at an experimental dinner insert earplugs before they start a specific course. At the 2014 Edinburgh Science Festival, for instance, there were well over 100 diners merrily chattering away at the start of a meal held in, of all places, Summerhall's now-disused dissection room (see Sensation, http://www.summerhall.co.uk/2014/sensation/). On this particular Saturday night, even the host had been having trouble keeping the roomful of increasingly boisterous diners in order. Anyhow, at the start of the meal, the diners were

encouraged to insert the pair of earplugs sitting innocuously on the table in front of them before biting into their first course, a particularly crispy bread roll prepared by Jelly and Gin (http://www.jellyandgin.com/). The effect was, quite frankly, astonishing. Within a matter of seconds, the entire roomful of babbling diners had fallen absolutely silent. Not a murmur was heard from anywhere in the room. What happened? Well, the diners were concentrating so avidly on their tasting experience that I think they simply forgot for a moment about conversing[n]. Note here also that with earplugs in, it becomes next to impossible to hear what the person next to you is saying while at the same time munching away on a noisy food (like the aforementioned crispy bread roll): Earplugs only dampen down the air-conducted sounds that convey both your neighbour's voice as well as some proportion of those crunching sounds. Crucially, they have no effect on the transmission of bone-conducted acoustic cues (that convey crunching sounds [83]).

While eating one course in silence can be both informative and fun, it is worth remembering that dining is very much a social activity [84]. Hence, the thought of eating an entire meal with earplugs in would not, one imagines, be all that successful. Sensory dinners, such as the one organized by Caroline Hobkinson, the first chef in residence at The House of Wolf restaurant in Islington, North London (see http://houseofwolf.co.uk/), tend to restrict the wearing of earplugs to just a single course (see Additional file 1). That said, a small band of experimental chefs and culinary artists are now playing with the concept of silent dining.

Silent dining: a sign of things to come?

In 2013, a restaurant called *Eat* in Greenpoint North Brooklyn, New York, initiated a monthly evening where the diners were expected to eat in silence [85]. On these 'silent dinner' nights, not even the waiters would speak over the course of the four-course dinner. This novel dining concept was initially so popular that the restaurant was full to capacity on these special nights [86]. It is interesting to consider that one of the benefits associated with being seated in a dining room where silence reins is that one may be able to hear more of those tantalizing sounds of food preparation emanating straight from the kitchen [86].

It would be easy to see the silent dining concept as a direct response to the increasing noise levels found in so many of our restaurants nowadays. Ironically, the bar where the chef at *Eat*, Nicholas Nauman, worked previously had been reported for noise violations [87]! However, Nauman himself puts the idea for laying on such silent events down to his time in an Indian monastery. Of course, many of those in religious institutions have, for centuries, been forced to eat in silence. That said, the aim in the institutional context has typically been rather different—it was never about bringing out the flavour of the food! One can perhaps think of silent dining as the sonic equivalent of the dine-in-the-dark restaurant[o]. For my tastes though, from a culinary perspective, the silent dining concept is rather more interesting than dining without being able to see one's food, never mind one's dining companions. It has to be said, though, that not everyone is impressed. Just take the following from Lockhart Steele, owner/creator of Eater.com, "*Novelty is everything in a certain corner of the dining world, no matter how fleeting … Dining in the dark, dining without talking — all that's left is eating without eating.*" (quoted in [87])[p].

It would certainly be interesting to follow-up on Srinivisan's [82] early research in order to determine whether by simply taking the typical restaurant bustle away, one can't deliver a significant boost to the diner's perception of the taste/flavour of an actual meal. Furthermore, given Seo et al.'s [56] intriguing findings, mentioned earlier, it remains to be seen whether extroverts might not end up enjoying this experience more than introverts [88].

Since 2008, the Australian culinary artist Honi Ryan has also been going around the world arranging silent dinners in people's homes [89][q]. The guests at these events are encouraged to communicate through gestures and expressions. Intriguingly, a Korean guest at one of these dinners actually reported "*that it is totally normal to be silent at the dinner table in Korea.*" (quoted in [90]), thus suggesting an intriguing cultural angle to the presence of noise at the dinner table.

So what should be absolutely clear by now is that there are a growing number of people out there complaining about the noise levels in many restaurants. At the same time, we have many diners who obviously crave the atmosphere and buzz that such an auditory backdrop provides. What, then, is the solution? One speculative possibility here might be to take the concept of silent disco into the arena of dining. Silent discos, where each person dances to their own, preferred, tune, have become a great hit amongst the younger generation over the last few years. Would a 'silent dinner' version of the same concept work, one might ask? Perhaps. But then again, perhaps not. My suspicion is that dining is just too much of a social/shared experience [84]. While dancing can be just as enjoyable without talking to those around you, dining out is as much also the opportunity for conversation as anything else. As Le Bernardin's four-star chef Eric Ripert puts in, "*When I want to eat in silence, which happens sometimes, either I stay at home or I go to a monastery. But when I go to a restaurant, it's to enjoy and share good times with friends and talk at the table.*" (quoted in [87]). Of course, only the future will tell whether the silent dining concept will really take off.

Conclusions

The available evidence suggests that the problem of too much noise while eating and drinking is affecting a growing number of us while dining out at popular restaurants and bars. While, to date, the majority of complaints have tended to come from the US, there is evidence that the problem is now spreading to many other Westernized countries as well [10,34]. Indeed, the uncomfortably high background noise levels found in many restaurants are increasingly being recognized as a very real and pressing concern by restaurateurs, restaurant critics, audiologists, and the general public alike. What is more, research from the laboratory suggests that loud noise can indeed affect the taste, flavour, and texture of food, often in an adverse manner. Although a number of solutions to combating noise in the restaurant/bar setting are now available, they all tend to be fairly expensive to implement. Hence, unless the diners really start to make some noise of their own, it is doubtful whether anything much will change, especially given the financial incentives associated with keeping the music level cranked up high [1-4,9].

Endnotes

[a]At least amongst those who are not put off from entering the establishment in the first place [91].

[b]In Los Angeles, for example, 18% of diners ranked noise top of their list of complaints in 2012, a 50% increase from the 12% figure reported back in 2010 [23].

[c]See, for example, the online definition at https://www.google.co.uk/?gfe_rd=cr&ei=gMhrU_vRLOfR8gfstoCYAg#q=noise+definition.

[d]Though here it is perhaps worth noting, Pettit's [20] early report suggests that the typical noise levels in a large restaurant would be in the region of 80 dB (and that was over half a century ago!). Meanwhile, Ferber and Cabanac were also complaining about excessively loud restaurant noise back in 1987 [35].

[e]Furthermore, only a limited amount of data was collected in McFadden et al.'s [19] Experiment 1, not to mention the fact that the researchers did not counterbalance the order in which the various conditions were presented—with the noisy condition always coming after the silent condition. Taken together then, one would perhaps be justified in not placing too much weight on these null results.

[f]Here, in hindsight, one might worry about the relatively small number of participants tested in this study and whether the experiment was simply underpowered to find the kinds of effects that the authors were interested in studying [92].

[g]One could perhaps think of masking as a lower-level sensory interaction, whereas the distraction account can be thought of as something that typically occurs at a somewhat higher level of information processing.

[h]It can be difficult for the psychologist to get ethics to present noise at the levels that are currently found in some restaurants, given its potentially damaging effect on hearing. Hence, it may not be so easy to reproduce the extended loud noise levels encountered by some of those who spend a lot of their time in restaurants.

[i]Though, that said, it is worth remembering that somewhat different results have sometimes been obtained in introverts and extroverts (cf. [56]).

[j]A restaurateur will be looking at an outlay of at least $10,000–$20,000 to make any serious in-roads in terms of soundproofing their restaurant [1,10].

[k]Some companies have started selling soundproofing paint, though it is not altogether clear just how effective a solution this actually provides (see [23] and http://www.audimutesoundproofing.com/soundproof-paint-soundproofing-paint.aspx).

[l]When it comes to the world of wine, one can also think of this as a distinction between synthetic and analytic tasting [93]. The former, involving the enjoyment of the overall experience (synthetic tasting) is what the average drinker is after, whereas analysing the component parts (i.e. analytic tasting) is normally the job of the professional wine taster.

[m]Given what we saw earlier (cf. [56]), one might wonder whether this result could be accounted for by individual differences—perhaps in terms of how introverted vs. extroverted the participants were.

[n]Something very similar happens, in fact, when diners put the earphones in while eating the "Sound of the Sea" seafood dish at Heston Blumenthal's The Fat Duck restaurant in Bray [70].

[o]Restaurants where you dine in complete darkness, often served by waiters who are blind [70,75].

[p]No surprise then that the restaurant has apparently closed down after the initial hype; see http://www.yelp.com/biz/eat-brooklyn-2, accessed on 24/06/2014.

[q]See http://silentdinnerparty.com/.

Additional file

Additional file 1: The Sensory menu. The menu is served by Caroline Hobkinson in 2012 at The House of Wolf restaurant (houseofwolf.co.uk) in Islington, North London.

Competing interests
The author declares that he has no competing interests.

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