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Effect of background noise on food perception

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ABSTRACT

We investigated the effects of auditory background noise on the perception of gustatory food properties (sugar level, salt level), food crunchiness and food liking. Participants blindly consumed different foods whilst passively listening to either no sound, or quiet or loud background white noise. The foods were then rated in terms of sweetness, saltiness and liking (Experiment 1) or in terms of overall flavour, crunchiness and liking (Experiment 2). Reported sweetness and saltiness was significantly lower in the loud compared to the quiet sound conditions (Experiment 1), but crunchiness was reported to be more intense (Experiment 2). This suggests that food properties unrelated to sound (sweetness, saltiness) and those conveyed via auditory channels (crunchiness) are differentially affected by background noise. A relationship between ratings of the liking of background noise and ratings of the liking of the food was also found (Experiment 2). We conclude that background sound unrelated to food diminishes gustatory food properties (saltiness, sweetness) which is suggestive of a cross-modal contrasting or attentional effect, whilst enhancing food crunchiness.

1. Introduction

Our perception of food is driven not only by what we taste and smell (Small & Prescott, 2005), but by a variety of other factors including colour (Shankar, Levitan, & Spence, 2010; Zampini, Sanabria, Phillips, & Spence, 2007), expectation (Cardello, 2007) and cognitive strategy (Prescott, Johnstone, & Francis, 2004). Sounds such as mastication noise from food breakdown (Zampini & Spence, 2004; c.f. Dijksterhuis, Luyten, de Wijk, & Mojet, 2007) and food-related sounds also contribute to food perception. For example, the sound of sizzling bacon can make bacon ice-cream seem more 'bacony' (Spence & Shankar, 2010). However, it is not clear whether sounds unrelated to food also modulate taste; we investigate this here, and also test whether this plays a role in food crunchiness perception and liking.

A surprisingly small amount of work has been conducted on the effects of background sound on food perception (Delwiche, 2004; Spence & Shankar, 2010) with research tending to focus on food properties conveyed by sound, such as 'crispiness' (Roudaut, Dacremont, Vallès Pàmies, Colas, & Le Meste, 2002; Zampini & Spence, 2004), rather than gustatory properties such as 'sweetness' or 'saltiness'. In an early investigation, Drake (1963) suggested that the sound of chewing and food-vibration cues contribute to food judgments. For example, Vickers and Bourne (1976) found that the amplitude of the sound produced by biting food was a significant cue for the crispness of food. Indeed, crispness is arguably an important factor in assessing food quality (Zampini & Spence, 2004) and an indicator of food pleasantness (Vickers, 1983).

More recently, Zampini and Spence (2004) manipulated the sound that arises when biting a potato crisp to examine the impact on food perception. The sound was recorded by a microphone, altered and relayed to the participant via headphones. They found that increasing the amplitude and high frequency components (>2 kHz) of the biting sound enhanced ratings of crispness and freshness. However, Christensen and Vickers (1981) did not find that masking food noise with background noise (100 dB radio static continuous noise via headphones) had an effect on judgments of crispness. Explaining these inconsistencies, Zampini and Spence argue that sound cues which appear to originate from the same source are more likely to enhance ratings (a principle of sensory integration; Stein & Meredith, 1993). While Zampini and Spence modified sounds emanating from food consumption, the static radio noise used by Christensen and Vickers would not have appeared to come from the same source as the food. It is premature, however, to conclude that sound must appear to arise from consumption in order to influence food perception because participants in Christensen and Vicker's study did not wear headphones in the quiet condition. Thus, any change in the noise condition may have been due to distortion of the sound from the food due to wearing headphones.

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Crocker (1950) suggested that "a loud noise ... may prevent entirely our ability to smell or taste" (p. 7). However, to the best of our knowledge, only two studies have tested the impact of background noise on gustatory cues. Christensen and Vickers (1981) found that thick gums were rated as *less* viscous in a noise condition compared to a silent condition. Similarly, Masuda, Yamaguchi, Arai, and Okajima (2008; discussed in Spence & Shankar, 2010) found that pretzels were rated as less moist whilst listening to white noise compared to no noise. It is possible that both viscosity and moistness are partly conveyed by sound, in which case the background noise may have masked this sound component leading to reduced reported intensities. The current study, therefore, directly examined the effect of background sound on gustatory food cues with no potential sound component (saltiness, sweetness).

There are several reasons why gustatory properties may be perceived as less intense in the presence of background noise. First, sound and taste may interact in the same manner as found in other sensory cortical structures (Schroeder & Foxe, 2005). For example, Wesson and Wilson (2010) found that a continuous 78 dB sound tone activated 19% of neurons within the rat olfactory tubercle. Further, the responses of 29% of these neurons to odour was changed when this tone was played, demonstrating a direct effect of sound on odour transduction. A second possible explanation is that contrast effects may extend cross-modally (van Wassenhove, Buonomano, Shimojo, & Shams, 2008), such that an intense background noise diminishes how strongly a gustatory cue is perceived. Thirdly, attention may be drawn away from the food stimuli to focus on background noise, influencing perception. Early visual cortex activation has been found to be bolstered by attention (Gandhi, Heeger, & Boynton, 1999), while activation is reduced to unattended stimuli (Muggleton, Lamb, Walsh, & Lavie, 2008). There is recent evidence that this extends to taste, with observations of attentional modulation of activity in primary taste cortex (Grabenhorst & Rolls, 2008). With regard to background noise, Boyle, Bentley, Watson, and Jones (2006) observed that unpleasantness ratings of pain were lower in background noise (85 dB). They argued that background noise distracted attention and thus dampened pain perception. The fourth possibility is an implicit association between sound type and food taste. Crisinel and Spence (2009, 2010) recently demonstrated that the names of bitter foods (e.g. "coffee", "beer") or salty ("salt", "crisps") were associated with low pitch sounds, whilst sweet ("sugar", "honey") or sour foods ("lime", "lemon") were associated with high pitch sounds (see also Holt-Hansen, 1968). The authors hypothesised that this relationship may arise via some underlying but as of yet unknown commonality between gustatory and auditory stimuli. Thus, different types of background noise might increase or decrease a particular taste depending on their association.

The liking of the food may also be affected by background noise. For example, restaurants typically play pleasant music to enhance the consumption experience. Music has been found to increase the consumption rate of soft drinks and beer, which likely represents a change in behaviour rather than perception (e.g. drinking songs promote a convivial environment associated with drinking, increasing consumption, Jacob, 2006; for an overview see Stroebele & De Castro, 2004). Of most relevance to the current study, Ferber and Cabanac (1987) found that the liking of sweet but not salty solutions was greater in the presence of 90 dB background noise, which they attributed to stress leading to a preference for sugar.

In Experiment 1, therefore, we directly tested for the first time whether gustatory food cues are reported to be less intense in noisy conditions, as suggested by previous findings (Christensen & Vickers, 1981; Masuda et al., 2008). We improved upon previous methodology by ensuring that participants wore headphones across all conditions, as opposed to only in noise conditions and asking participants to rate gustatory cues with no sound component (saltiness, sweetness). We also tested whether only foods with a strong sound-conveyed component are affected by background noise by testing both crunchy and soft food, and whether background noise affected the liking of the foods. To achieve this, participants were tested under a baseline no noise condition and two levels of background noise.

2. Experiment 1

2.1. Method

2.1.1. Participants

Forty-eight undergraduate and postgraduate students (39 female and 9 male) from Manchester University volunteered to participate in this experiment in return for course credit or payment. During recruitment, participants were told that the study involved assessing foods on several perceptual attributes. Participants' ages ranged from 19 to 39 years (mean = 22 years), five smoked, five reported mild cold symptoms and none reported any food allergies. All participants provided written informed consent prior to the experiment and our protocol was approved by the School of Psychological Sciences research ethics committee.

2.1.2. Stimuli

Commercially available foods were used as stimuli. Both savoury and sweet stimuli were selected for the soft and crunchy food categories. The savoury stimuli were Pringles Original Salted Crisps (crunchy) and Cathedral City Mild Mini cheese (soft). Sweet stimuli were Sainsbury's Nice Biscuits (crunchy) and Sainsbury's 'all butter' mini Flapjack (soft). Carr Water crackers were included as a dummy stimulus to promote full scale-usage (crackers are neither salty nor sweet). Stimuli were presented broken into mouth-sized pieces (approximately 1 cm cubed or 2 cm squared in size).

2.1.3. Apparatus

The participant sat at a table upon which there was a panel to hide food stimuli from view (see Fig. 1). The participant wore headphones (ProSound audio headphones, Maplin Electronics, Rotherham, UK) which were open-backed to minimise the distortion of chewing sounds. White noise was delivered through these at either at 45–55 dB (Quiet) or 75–85 dB (Loud). There was also a no white noise condition (Baseline). Note that variability was due to unavoidable low-level noise arising from outside the testing room. A decibel meter (Digital Sound Level Meter, CEM DT-805, ShenZhen, China) was used to manually calibrate the volume.

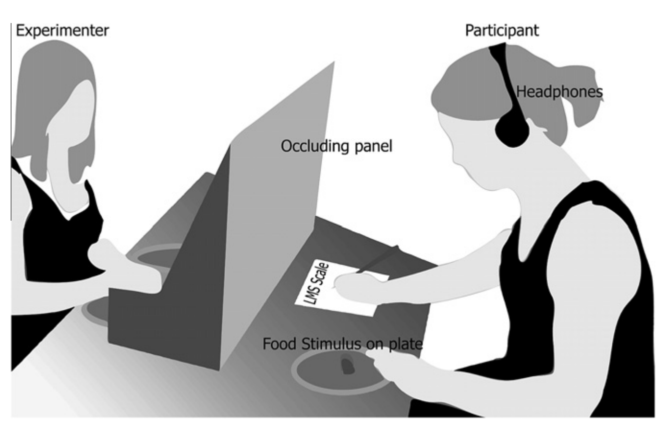

Fig. 1. A cartoon depiction of the experimental set-up.

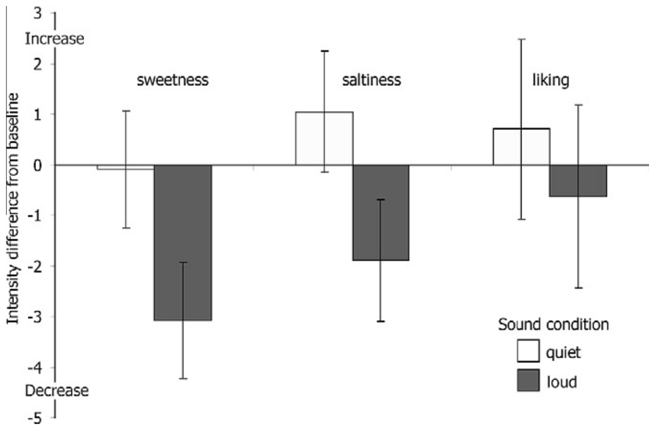

Fig. 2. The effect of quiet and loud background sound level on sugar, salt and liking intensity in Experiment 1, relative to the baseline condition; a negative value indicates a lower level than baseline and a positive value a higher level. Error bars (2 SEM) were calculated with the following correction to help incorporate the repeated-measures design. The mean rating for each participant across trials was calculated and from this, the mean rating across participants and trials was subtracted to give a correction value specific to each participant. These correction values were then subtracted from the scores of each participant. Standard error was then calculated from these adjusted scores in the normal fashion (see Masson & Loftus, 2003).

2.1.4. Design

A repeated-measures design was used with Sound (Baseline, Quiet, Loud), and Hardness (Crunchy, Soft) as factors. The dependent variables were reported Saltiness, Sweetness and Liking.

2.1.5. Procedure

Participants were told at the start of each trial to close their eyes and rest their hands on the table in front of them. The experimenter placed a paper plate containing a food stimulus on the table touching the participant's fingers to indicate to the participant to pick up the stimulus and eat it. After swallowing, the participant opened their eyes and then rated the stimulus using a labelled magnitude scale (Green, Shaffer, & Gilmore, 1993; as used recently by Zampini et al., 2007) and a labelled affective magnitude scale (Schutz & Cardello, 2001). These scales have labels (e.g. intense, somewhat intense) strategically placed to fit according to their perceived magnitude, relative to other labels and their positions. Scores were measured to the nearest mm. The ratings of saltiness, sweetness and liking were done in a random order. Participants were asked to take a sip of water between each trial.

The Sound condition was blocked with the order counterbalanced across participants. Trial order within each block was randomized. There were 25 trials per participant, which took approximately 30 min. Afterwards, all participants were fully debriefed as to the nature of the experiment.

2.2. Results

Two dependent variables were computed for each type of rating (Saltiness, Sweetness and Liking) by subtracting the baseline ratings from the quiet condition and loud sound conditions (e.g. Prescott et al., 2004). This controlled for individual differences in ratings in the baseline condition. For sweetness, six data points were outlying and were corrected for (3.1% of the data was outlying; henceforth outliers are defined as exceeding 99% of the normal distribution surrounding the mean [±2.5 standard deviations], and are corrected for by being replaced with the next most extreme but non-outlying data-point ±1, e.g. Field, 2005). There were seven (different) data points in Saltiness and Liking data that were outlying and corrected for (3.6% of the data for each dependent measure was outlying). Separate ANOVAs were conducted, with two repeated-measures factors of Hardness (crunchy versus soft) and Sound (quiet versus loud) for the different dependent variables (Sweetness, Saltiness and Liking).

There was support for the hypothesis that background noise would reduce the reported intensity of perceptual food attributes. A significant main effect of Sound was found for both sweetness [$F(1, 47) = 6.715$, $p = .0132$; Quiet average $-.090$, Loud average -3.07] and saltiness measures [$F(1, 47) = 6.019$, $p = .0183$; Quiet average 0.75, Loud average -1.60]. This shows that both sensory attributes were rated lower in the Loud condition than in the Quiet condition (see Fig. 2).

Hardness and Sound conditions did not interact for either dependent measure [sweetness, $F(1, 47) = 1.735$, $p = .194$; saltiness, $F(1, 47) = 2.526$, $p = .119$]; further, there was also no main effect of Hardness [sweetness, $F(1, 47) = 1.628$, $p = .208$; saltiness, $F(1, 47) = 1.522$, $p = .223$]. This indicates that background sound affected both crunchy *and* soft food. One-sample *t*-tests were used to compare the change scores, collapsed across crunchy and soft stimuli, to zero. In the Loud condition, sweetness ratings significantly differed from baseline [$t(47) = 2.897$, $p = .006$], but saltiness did not [$t(47) = 1.59$, $p = .118$]. In the Quiet condition neither rating differed from baseline [$p > .05$].

Although descriptively background noise influenced food liking in the same manner as sweetness and saltiness, this was not statistically supported: there was no main effect of Hardness [$F(1, 47) < 1$] or Sound [$F(1, 47) = 2.332$, $p = .133$] on liking and the variables did not interact [$F(1, 47) < 1$].

2.3. Discussion

We observed an effect of background noise on the participants' ratings of both sweetness and saltiness. In both cases, the food was reported to taste less intense in the noisy condition. Thus, for the first time we have observed an effect of background noise on purely gustatory, rather than sound-mediated food cues or more complex attributes (viscosity and moistness; Christensen & Vickers, 1981; Masuda et al., 2008) which may have included some sound components. The reasons for this effect will be considered in Section 4. Note that gustatory ratings were affected only in the noisy condition suggesting that the effect arises when noise exceeds some critical level. As crunchy foods and soft foods were *both* affected by increasing background noise levels, it is unlikely that these effects can be accounted for solely by the modulation of the crunchy sounds of the food. Nevertheless, to explore this issue further, we directly tested the effect of background sound on food crunchiness in the next experiment.

Although descriptively food was less liked in the noisy as opposed to less noisy condition, this was not statistically supported. This contrasts with Ferber and Cabanac (1987) who found sweet stimuli were more liked in noisy conditions. It should be considered, however, that food liking effects could have been confounded by whether or not the participant liked or disliked the background noise (several participants reported after the study that they liked the background, for example finding it "relaxing"). This is also tested for in Experiment 2.

3. Experiment 2

We had two objectives for the following experiment. Our first was to test whether sound-conveyed food cues are affected by background noise and how this compares to the ratings of gustatory food cues. If the hypothesis that sounds cues must closely match auditory food cues (in quality and location) in order to have an effect is correct (Zampini & Spence, 2004), there should be no effect of background noise on ratings of crunchiness. If, however, gustatory sound cues are reported *more* intense in noise, this would disprove this hypothesis. On the other hand, if background noise masks sound-related food cues (as suggested by Christensen & Vickers, 1981) then ratings of crunchiness should decrease.

Our second aim was to assess whether the liking (or disliking) of the background noise affects the liking of food consumed in the presence of the noise. As discussed, it is possible that the liking of the background noise itself may have confounded food liking ratings in Experiment 1. Since food liking has been shown to be influenced by environmental factors before (see Macht, Roth, & Ellgring, 2002), we measured how liked the background noise was in this study at the end of the experiment in addition to obtaining ratings of liking of the food itself on each trial.

Methodologically, it is important to use liked, neutral and disliked stimuli as effects of food liking may only emerge over the full range of stimuli; restricting the range of stimuli may hide such effects (e.g. there may be no relationship between IQ scores and mathematical ability for members of the high IQ society, Mensa, but such a relationship may exist in the general population; see, Kantowitz, Elmes, & Roediger, 2008, p. 42). We thus included stimuli which are commonly liked and disliked by different people, such as Salt and Vinegar, Sweet Berry and Marmite rice crackers (out of a UK panel of 1030 individuals, 53% liked and 30% disliked Marmite, Unilever Internal Report., 2009). In order to reduce the possibility that participants might remember the ratings they had given a particular foodstuff in a previous condition we used stimuli that were similar in texture and crunchiness (rice cakes) and differed only in taste. Also, to further reduce familiarity with the stimuli and to promote full scale usage we included dummy trials with additional stimuli (of different tastes).

3.1. Method

3.1.1. Participants

Thirty-four undergraduate and postgraduate students (19 female and 15 male) from Manchester University participated in this experiment in return for course credit or payment. Participants' ages ranged from 20 to 49 years (mean = 28 years). None reported any food allergies.

3.1.2. Stimuli and apparatus

Only the stimuli here differed from those used in Experiment 1. All foods used were commercially available and fell into three categories: sweet, salty, or as dummy stimuli. Sweet stimuli were Berry and Caramel flavoured rice cakes (Snack a Jacks, UK), savoury stimuli were Salt and Vinegar and Marmite flavoured rice cakes (Marmite Rice Cakes, Unilever, UK). Dummy stimuli were organic rice cakes (Finger Foods Organic Rice Cakes, Organix, UK), Cream and Chive rice cakes, Sweet Chilli rice crackers (Snack a Jacks, UK), and softened organic rice cakes (sprayed with water). After the experiment, participants also rated their liking of the background noise and each flavour in general.

3.1.3. Design and procedure

The experiment was based on a repeated-measures design with Sound (no noise, quiet and loud background noise) and food-Type (Savoury, Sweet) as factors. The dependent variables were reported flavoursomeness, crunchiness, and liking (in Experiment 1, Salt and Sweet dependant variables were used; here we collapse these onto one flavoursomeness intensity variable to keep the number of ratings to an acceptable level). Flavoursomeness and crunchiness were measured on labelled magnitude scales whilst liking was measured on a labelled affective magnitude scale (as described earlier). At the end of the experiment, participants rated how much they liked the background noise over the whole study on a labelled magnitude scale. The remainder of the design and procedure was identical to Experiment 1.

Fig. 3. The effect of quiet and loud background sound on flavoursomeness, crunchiness and liking intensity ratings in Experiment 2, relative to the baseline condition.

3.2. Results

Dependent variables were computed for each condition as before, by subtracting baseline (no noise condition) flavoursomeness, crunchiness and liking ratings from Quiet sound and Loud sound condition ratings. In terms of outliers, 1 flavoursome, 5 crunchiness and 3 liking outliers were detected and corrected for (0.7%, 3.7% and 2.2% of the data was outlying for each respective dependent measure). Separate ANOVAs were conducted on reported flavoursomeness, crunchiness and liking with repeated-measures factors of food-Type (Savoury, Sweet) and Sound (Quiet, Loud) as independent variables.

In terms of crunchiness, the main effect of Sound was significant [$F(1, 33) = 6.88$, $p = .013$], with stimuli in the Loud condition rated significantly *more* crunchy than stimuli in the Quiet condition (see Fig. 3). Loud data was peaked (kurtosis = 1.4) so sign tests were also conducted, revealing that ratings under Loud conditions differed from baseline at trend level ($Z = 1.89$, $p = .059$) but those under Quiet conditions did not ($Z = .51$, $p = .61$). The main effect of food-Type was non-significant [$F(1, 33) = 1.43$, $p = .24$] as was the interaction between factors [$F(1, 33) = 1.13$, $p = .30$].

In the analysis of flavoursomeness, there were *no* significant main effects or interactions ($p > .05$), in contrast to the results of Experiment 1.

With regard to liking, we first assessed whether there was an overall effect of background noise on liking. The above ANOVAs were repeated using food liking as the dependent variable. As predicted, there were no main effects or interactions ($p > .05$), replicating the results of Experiment 1.

As our hypothesis was that food liking and background noise liking interact, it was important to identify foods which were both liked, neither liked nor disliked, and disliked (consider that if all the participants liked the food, in essence we have an incomplete design which hinders interpretation). We assessed this by testing whether there were uneven group sizes (Table 1) using Chi-square tests. This was true for all stimuli [$\chi^2(2) > 18.41$, $p < .0002$] except the Marmite stimulus [$\chi^2(2) = 3.06$ $p = .22$]. To test for a relationship between the liking of background noise (mean = −7.32, std = 14.82) and food liking[1] two correlations were conducted, one using only the Marmite stimulus data (where we expect to observe the effect of background noise liking as there is a sufficiently large

[1] The liking of the background noise did not correlate with flavoursomeness [$r = -.041$, *two-tailed*, $p = .59$] or crunchiness [$r = .073$, *two-tailed*, $p = .41$].

Table 1
Number of participants who liked and disliked each stimulus in Experiment 2.

Food	Like		
	Yes	No	Neither
Marmite	10	8	16
Salt and vinegar	25	6	3
Caramel	23	4	7
Berries	25	1	8

range of liking data for the effects to appear over and thus be detectable) and the other using the data from the remaining stimuli (where we are less likely to observe an effect due to range restriction, e.g. Kantowitz et al., 2008). For the Loud condition, liking and background noise liking correlated for Marmite stimuli [$r = .55$, *two-tailed*, $p = .00089$; one outlier excluded], but not for the other stimuli [$r = .023$, *two-tailed*, $p > .05$; one outlier excluded]. To control for baseline differences in liking, another correlation was run using an index of liking change between the Quiet and Loud condition, produced by subtracting liking in the Quiet condition from liking in the Loud condition. Marmite liking on this measure again correlated with background noise liking [$r = .47$, *two-tailed*, $p = .0069$; two outliers excluded], while there was no correlation for liking of the other foods [$r = .074$, *two-tailed*, $p > .05$; one outlier excluded].

3.3. Discussion

Sound-conveyed food cues were indeed affected differently by increasing sound levels. We found that food crunchiness was enhanced in a noisy compared to less noisy environment. This contrasts with the findings of Christensen and Vickers (1981), which as we suggested earlier may have been affected by participants only wearing headphones in the noise condition (leading to a distortion of mastication sounds in these conditions). Our finding extends those of Zampini and Spence (2004), who found that the crispness of potato crisps was enhanced when biting sounds were amplified, by demonstrating that background noise and food sound need not be related to each other for such effects to occur.

In contrast to Experiment 1, the gustatory food rating (flavoursomeness) was unaffected by background noise. We discuss later how this may have arisen due to a difference in cognitive strategy across experiments (synthetic here versus analytic in Experiment 1, see Le Berre et al., 2008; Prescott et al., 2004).

One stimulus (Marmite) was identified as being liked and disliked by similar numbers of people. As predicted, food liking and background noise liking correlated for this stimulus, but not for the remaining (mostly liked) stimuli. This cannot be explained by people who like the strong flavour of Marmite also tending to like the loud background noise, as there was also a correlation between the change in liking between the Quiet to the Loud noise conditions with the liking of the background noise. Thus, the effect that the noise had on liking was related to how much the background noise was liked or disliked. This is discussed further below.

4. General discussion

We found evidence for three different effects of background noise on food perception. The first is a dampening of gustatory cue intensity. Food saltiness and sweetness *diminished* when eaten in the presence of loud compared to quiet background noise (Experiment 1). Second, sound-mediated food cues were perceived *more* intensely in noise: we found that food was reported to taste crunchier in the presence of background noise (Experiment 2). Thirdly, background noise liking and food liking were found to interact; the effect of noise on the liking of the food correlated with the liking of noise itself (Experiment 2).

With regard to effects on gustatory cues, background noise was found to reduce the reported intensity of the sweetness and saltiness of foods in Experiment 1. However, there was no corresponding effect on ratings of how 'flavoursome' the foods were rated in Experiment 2. One possible explanation for this is that the term 'flavoursome' has an unintended affective connotation (implying a food is tasty and thus liked). Therefore, the null effect of noise on liking may have diluted any effect on gustatory cues. Alternatively, this difference might be due to a change in cognitive strategy across studies. In Experiment 2, a synthetic dependent measure was used as opposed to the analytical measures used in Experiment 1 (for an overview of these concepts, see Le Berre et al., 2008; Prescott et al., 2004). The synthetic task may also have prompted a taste expectation (e.g. caramel, berry, Marmite-flavour), which acted to standardise flavoursome ratings over the different noise conditions (Woods, Poliakoff, Lloyd, Dijksterhuis, & Thomas, submitted for publication). A final possibility is that attention was drawn away from gustatory cues by asking participants to also provide ratings of crunchiness.

In the introduction, four accounts on how background noise may affect taste were discussed. These included a direct interaction between sensory cortices (Schroeder & Foxe, 2005; Wesson & Wilson, 2010), a cross-modal contrast (van Wassenhove et al., 2008), attentional (Grabenhorst & Rolls, 2008) and association effects arising due to implicit links between sounds and tastes (Crisinel & Spence, 2009). Further research is required to disambiguate these accounts. The attentional account would predict that the same effects should be evident when modulating attentional load by other means, such as dual tasks. However, a cross-modal contrasting effect would only be apparent when presenting background stimuli. If it is a more general contrasting effect it would extend to background stimuli in other sensory modalities (e.g. vibrotactile or visual); conversely, background noise could affect the rating of other sensory stimuli. The implicit association account, on the other hand, predicts that it is the *quality* of background auditory noise that determines the effect on gustatory perception.

In terms of sound-conveyed cues, food was reported *crunchier* in loud background noise (Experiment 2). Our findings extend previous work (Zampini & Spence, 2004) by showing that sounds *unrelated* to food consumption can also enhance reported crunchiness. Nevertheless, it is likely that it is necessary for the frequency range of the background noise and the noise emitted by consumption of crunchy food to overlap in order for this effect to occur.

Although background noise did not have an overall effect on the liking of food, a correlation was found between the liking of the background noise and the change in the liking of the food between quiet and loud conditions (Experiment 2). Only the Marmite rice cracker, however, was suitable for testing this relationship; it was the only one that sufficient numbers of people both liked and disliked. This finding demonstrates that background noise can impact on the liking of food, adding to findings that liking can be affected by emotional state (Macht et al., 2002) and various environmental factors (Stroebele & De Castro, 2004). On the other hand, the causality might be in the opposite direction: if people liked food more in noisy conditions, this could have carried over to their appraisal of the noise. Additional research is needed to establish the causality and generalisability of this relationship.

In conclusion, we found evidence that auditory background noise reduced the intensity of gustatory food cues but increased the intensity of sound-conveyed food attributes. We also found evidence for a relationship between the liking of the background noise and the change in the liking of the food consumed in the presence of noise. Further research is required to distinguish between the possible underlying mechanisms of these effects.

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