Novel flavours paired with glutamate condition increased intake in older adults in the absence of changes in liking

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Novel flavours paired with glutamate condition increased intake in older adults in the absence of changes in liking

Maria Dermiki[a], John Prescott[b], Laura J Sargent[a], Joanne Willway[a], Margot A.Gosney[c] and Lisa Methven [a,*]

[a]Department of Food and Nutritional Sciences, University of Reading, Whiteknights, Reading, RG6 6AP, UK

[b]*TasteMatters* Research & Consulting, Sydney, Australia [Prescott@taste-matters.org]

[c]Clinical Health Sciences, University of Reading, London Road, Reading, RG1 5AQ, UK

***Correspondence to: Dr Lisa Methven, Department of Food and Nutritional Sciences, University of Reading, Whiteknights, Reading, RG6 6AP, UK, email: l.methven@reading.ac.uk

Abstract

Previous research on the repeat exposure to a novel flavour combined with monosodium glutamate (MSG) has shown an increase in liking and consumption for the particular flavour. The aim of the current work was to investigate whether this could also be observed in the case of older people, since they are most affected by undernutrition in the developed world and ways to increase consumption of food are of significant importance for this particular age group. For this study, 40 older adults (age 65-88) repeatedly consumed potato soup with two novel flavours (lemongrass and cumin) which were either with or without a high level of MSG (5%w/w). A randomized single blind within-subject design was implemented, where each participant was exposed to both soup flavours three times over 6 days, with one of the soup flavours containing MSG. After three repeat exposures, consumption increased significantly for the soups where the flavours had contained MSG during the repeated exposure (mean weight consumed increased from 123 to 164 g, p=0.017), implying that glutamate conditioned for increased wanting and consumption, despite the fact that the liking for the soup had not increased.

Highlights

- Glutamate can condition increased food consumption in older adults
- Older adults increased consumption of novel flavoured soups paired with glutamate
- Older adults did not increase liking of novel flavoured soups paired with glutamate

Keywords

Conditioned liking, conditioned intake, wanting, consumption, glutamate

Introduction

While repeated exposure alone can produce increased liking for food/beverage flavours (Methven, Langreney, & Prescott, 2012), it is thought that most flavour or food preferences are formed through associative learning in which the flavour is paired with a liked taste such as sweetness (flavour-flavour learning, FFL; (Yeomans, Mobini, Elliman, Walker, & Stevenson, 2006) or with ingested nutrients (flavour-consequence learning, FCL) including carbohydrates (Yeomans, Leitch, Gould, & Mobini, 2008) and fat (Kern, McPhee, Fisher, Johnson, & Birch, 1993). Nutrient pairing has been shown to lead to ~~produces reliably strong increases in~~ liking for a paired flavour in some studies (Brunstrom & Mitchell, 2007; Kern, et al., 1993; Yeomans, Leitch, et al., 2008) but not all (Remy, Issanchou, Chabanet, & Nicklaus, 2013). Typically the effect is only successful under conditions in which the nutrient is valued. Hence, learning is strongly dependent on hunger state, an observation which emphasizes the key role of the metabolic consequences of the nutrients in facilitating the increased flavour liking (Mobini, Chambers, & Yeomans, 2007). It is however noted that where the taste is generally associated with nutritive value, for example sweetness and sugar, FFL can still result from low-nutritive value (low calorie) sweetness pairings (Privitera, Mulcahey, & Orlowski, 2012).

FCL has also been demonstrated with glutamate in the form of its sodium salt, monosodium glutamate (Prescott, 2004; Yeomans, Gould, Mobini, & Prescott, 2008). The metabolic underpinnings of this process are less clear than they are for the similar effects produced by sugar or fat, both sources of energy. However, glutamate is an amino acid and the human body requires sources of amino acids and protein, so the fact that glutamate increases savoury taste and food pleasantness may increase motivation to consume foods as a response to ensure adequate protein intake (Murphy, 1987). There are also data suggesting an important metabolic role for glutamate as an intestinal energy source (Reeds, Burrin, Stoll, & Jahoor, 2000).

Motivation to consume sufficient protein is the basis of the “protein leverage hypothesis” whereby it is proposed that humans have an appetite for protein which within low protein diets can lead to excessive energy intake. In a recent study by Gosby, et al. (2011), lowering protein in the diet (from 15% to 10%) led to higher total energy intake which was

predominantly consumed through savoury-flavoured foods. This supports the theory that savoury taste signals for protein.

Repeatedly pairing a novel soup flavour with ingested glutamate was found to produce a substantially stronger preference than either simple repeated exposure to the soup flavour or to the soup flavour paired with glutamate but ingested in only nominal amounts, a condition equivalent to FFL (Prescott, 2004). In a subsequent study (Yeomans, Gould, et al., 2008), conditioned flavour liking from ingested glutamate added to soups was also observed. In addition, this later study also examined the impact of glutamate-conditioned flavours on post-conditioning intake and hunger. Relative to a control condition in which the soup did not contain added MSG, pairing with MSG produced a significant increase in *ad-libitum* soup intake following conditioning. As well, tasting the soup whose flavour had been paired with MSG increased ratings of hunger, again an effect not evident in the control condition.

In contrast to measures of liking, hunger might be considered a motivational consequence of ingested MSG in such conditioning paradigms. Distinctions between affective (liking) and motivational (wanting) aspects of consumption have been highlighted by Berridge (Berridge, 1996, 2009), initially as an explanatory principle underlying drug addictions. The two psychological processes of liking and wanting operate at explicit (deliberative) and implicit (automatic) levels (Finlayson & Dalton, 2012) and there have been a number of studies that focused on developing methodologies in order to understand the extent to which this distinction applies to food consumption (Finlayson, King, & Blundell, 2006, 2007) and the importance of the distinction in providing explanations for food-related issues such as obesity and binge-eating (Finlayson, Arlotti, Dalton, King, & Blundell, 2011; Finlayson, King, & Blundell, 2008; Griffioen-Roose, Finlayson, Mars, Blundell, & de Graaf, 2010; Temple, et al., 2009).

However, whereas obesity is of concern to the main stream western populations, the incidence of under-nutrition is widespread among older people (Age Concern, 2006) and

97 factors that may increase intake or hunger are consequently of practical interest. One of
98 the physiological factors that results in reduced food intake is the natural decline of taste
99 and olfaction due to ageing (Kenway, et al., 2004; Methven, Allen, Withers, & Gosney,
100 2012; Schiffman & Warwick, 1993), or due to diseases and medication (Nolan, 2001;
101 Schiffman, 2007; Schiffman, et al., 2000; Winkler, Garg, Mekayarajjananonth, Bakaeen, &
102 Khan, 1999), which can lead to a reduced appreciation and interest in food. Moreover,
103 perhaps as a consequence of such sensory deficits, it is not at all clear that either FFL or FCL
104 operate as effectively in elderly populations as they do in the younger age groups that have
105 been studied to date.

106

107 Here we report the results of a study in which the pairing of MSG with a novel soup flavour
108 produced conditioned increases in soup consumption in the absence of conditioned liking.
109 In this particular study, we investigated how repeated exposure to MSG could influence
110 both liking for paired soup flavour as well as willingness to consume the soup in older
111 healthy adults.

112

113 **Materials and Methods**

114 *Design*

115 This single blind study used a within subjects design to measure the effect of MSG-
116 enhanced soup on liking and consumption by older adults, following repeat exposure. The
117 participants were asked to attend a pre-~~training~~ conditioning session (session 1, S1) and a
118 post-~~training~~ conditioning session (session 8, S8) at a central location (the university). At
119 the pre-~~training~~ conditioning session they were required to take home 6 cans of soup for
120 their consumption over the week. Two different flavours of soup, cumin and lemongrass,
121 were used account for mere exposure effects of increased liking to the flavour regardless of
122 the addition of MSG. Each flavour was consumed on alternate days throughout the week
123 (Table 1). The order in which the flavours were consumed was balanced across
124 participants. For each group one soup contained added MSG, the other did not. In pre-
125 and post- ~~training~~ conditioning sessions, the soups tasted and consumed did not contain
126 added MSG.

TABLE 1 ABOUT HERE

Participants

Forty volunteers (10 men, 30 women; 65- 88 years old, mean age: 73.7±5.5 years) were recruited from a database of healthy older volunteers whom had previously stated an interest in taking part in research studies. Each participant received a participant information sheet and on agreeing to take part in the study they completed a consent form. A screening questionnaire determined their eligibility to take part in the study; exclusion criteria were the existence of relevant food allergies or intolerances, taking medications known to affect appetite or taste and age under 65 years. The volunteers self-reported height and weight, from which their BMI was calculated. The majority of participants were in the healthy weight BMI category, the mean BMI was 23.7 kgm^{-2}, the median was 23.1 kgm^{-2}, and the overall range was 18.6 to 31.9 kgm^{-2}. No volunteers were reportedly underweight (<18.5 kgm^{-2}), eight were in the overweight category (25 to 29.9 kgm^{-2}) and two in the obese category (30 to 39.9 kgm^{2}).

Participants were allocated randomly to one of two groups (~~MSG^{+} and MSG^{-}~~ Group 1 or Group 2) which determined which of the soups to be taken home contained added MSG and which did not. Each group was then further segmented in terms of which flavour soup they would consume on the pre- and post- conditioning~~training~~ sessions (the one exposed with MSG or the one exposed without MSG). The two groups did not differ in terms of gender (both groups had 5 men and 15 women) or differ significantly in terms of age (MSG^{+}: 72.8 ±4.9 years; MSG^{-}: 74.6 ±6.1 years, p=0.298). One participant failed to attend post-~~training~~conditioning, so her results were excluded from the study. The project was given approval to proceed by the University of Reading Research Ethics Committee (study number 11/41).

Samples

A potato soup was prepared as a base and two different concentrated flavour

preparations, lemongrass and cumin (Treatt, Bury St Edmunds, UK) were added to create the two different soup flavours. The soups were then processed in a canning retort at 121°C in either 400 ml or 120 ml cans, the larger size for the consumption tests and the smaller sizes for the repeat exposure tastings. The particular flavours chosen were considered novel for this age group and were used in order to avoid any effects of familiarity on liking and consumption of the soups. All soups were prepared in the pilot plant in University of Reading, following good manufacturing practices (GMP) and Hazard Analysis Critical Control Points (HACCP). To half of the soup samples provided during the ~~training~~ conditioning sessions (see below) 5% MSG w/w was added.

Procedure

Pre-~~training~~ conditioning session (session 1): Volunteers tasted both of the two flavours of soup and rated their liking for them on a standard 9-point hedonic category scale (1 = dislike extremely and 9 = like extremely). They were also asked to ~~rank their preference~~state which of the two samples they preferred. Soups were presented in a balanced order and participants were asked to rinse their palate with water between samples. Additional questions were asked on familiarity of each soup flavour as well as questions on appetite and mood. These were rated using unstructured line scales (results scaled 0-100) with anchors at both ends (Table 1). They were then presented one soup for consumption. Each volunteer was asked to eat as much soup as they wanted; they were provided with both a bowl of soup (250 ml) alongside an additional thermos flask of soup (total amount of soup was 400ml). Consumption weight was calculated. Then participants were asked further questions on appetite (Table ~~1~~ 2 Q7-8).

~~Training~~ Conditioning sessions (Sessions 2 – 7): The volunteers took home six cans of soup (120 ml), three of each flavour, to consume on alternate days over the 6 days with one flavour containing added MSG. Instructions were given to each volunteer on how to reheat the soup and they were asked to consume one can of soup (120ml) at their normal lunch time each day, recording the time they ate and any other comments on a chart provided.

Post-~~training~~ conditioning (Session 8): During the post-~~training~~conditioning session, held at the central location (University), the volunteers repeated the liking and preference test and answered the same questions on familiarity, appetite and mood as in the pre-~~training~~conditioning, and in the same order (session 1). They were also presented with the same soup for consumption as they had been in session 1. Moreover, they were asked to eat the same breakfast at the same time on both the pre- and post- conditioning~~training~~ days and not to consume anything apart from water between breakfast and ~~lunch~~the midday session. Both pre- and post- conditioning~~training~~ sessions were commenced at midday with participants seated in isolated sensory booths.

TABLE ~~1~~ 2 ABOUT HERE

Statistical analysis

Analysis of the data was conducted with XLSTAT (Addinsoft, version 2011.4.01). Correlation tests were done using Pearson correlation matrix. Comparison of measures between flavours and sessions were carried out using t tests. The effect of soup flavour, exposure to MSG and gender on the difference in consumption, liking and familiarity pre- and post ~~training~~ conditioning were carried out using analysis of variance. *Difftest* (Statbasics, version 2.00) was used to determine the significance of the preference results. For all tests, significance was established at $p<0.05$.

Results

Liking

Liking ratings for the soups were low with mean liking ratings across both flavours being 5.7 and 5.4 out of 9 at sessions 1 and 8 respectively. The liking of the soups was significantly affected by the flavour ($F(1,148)=3.90$, $p=0.05$) with the lemongrass scoring lower than the cumin flavour in both S1 (mean rating 5.3 compared to 6.1) and S8 (5.3 compared to 5.6). However, liking was not significantly affected by the session (pre- to post conditioning~~training~~) ($F(1,148)=0.49$, $p=0.48$), the exposure group ($F(1,148)=1.05$, $p=0.31$)

or gender (F(1,148)=0.21, p=0.65). There were no significant interactions between any of the treatment effects.

The difference in liking between the pre- and post conditioning~~training~~ was not significantly affected by the soup flavour (F(1,73) =0.95, p=0.33), whether that flavour had been previously paired with MSG (F(1,73) =0.01, p=0.93), or gender (F(1,73) =0.60, p=0.44), and there was no significant interaction between flavour and exposure group (F(1,73)=0.90, p=0.35) (Figure 1). There was a significant correlation between familiarity and liking, across all soup flavours and sessions (r=0.25, p=0.002).

The scores for "would you choose this soup" were below the mid-point on a 100 point scale (mean values of 37.8 and 35.6 across both soup flavours at S1 and S8, respectively). There were no significant effects of flavour (F(1,147)=2.59, p=0.11), session (F(1,147=0.23, p=0.63), exposure group (F(1,147=1.14, p=0.29) or gender (F(1,147=0.09, p=0.76) on the readiness to choose the soup, and no significant interactions between these factors.

FIGURE 1 ABOUT HERE

Preference

~~In neither S1 nor S8, was t~~There was no significant~~any~~ difference in the number of subjects who preferred the cumin ~~one soup~~ flavoured soup over ~~another~~ the lemongrass flavoured soup in either S1 or S8 (n=22 cumin, n=17 lemongrass; at both sessions).

Familiarity

Familiarity was rated low for both soups in S1 (mean values out of 100: cumin 30.3, lemongrass 20.6), confirming initial judgments of flavour novelty. Significant effects on changes in familiarity between the pre- and post- exposure sessions were seen as a function of flavour (F(1,71)=3.89, p=0.025) and gender (F(1,71)=3.89, p=0.05), but not exposure group (F(1,71)=0.15, p=0.70). Familiarity increased significantly from S1 to S8 for the lemongrass flavour (t (76)= 3.44, p=0.001) but not for the cumin flavour (t (74) = 1.17,

p=0.25). The apparent difference in change in familiarity as a function of exposure with MSG shown in Figure 2 was not significant (interaction between flavour and exposure group: F(1,71)=1.27, p=0.26), whereas the familiarity of the lemongrass flavour increased between the sessions whether exposed with MSG or not.

FIGURE 2 ABOUT HERE

Appetite and Mood

The participants pre-lunch hunger, desire to eat and mood ratings did not change significantly between sessions (Figure 3) (t(74)=0.93, p=0.35; t(74)=0.63, p=0.53; t(74)=0.05, p=0.96 respectively) . The mean hunger and desire to eat ratings were mid-scale implying the participants were moderately hungry at the time of the tests, and the mean mood rating was high implying the participants were in a pleasant mood.

FIGURE 3 ABOUT HERE

Although post consumption the overall mean satiety ratings were not higher in S8 compared to S1 (t(76)=1.29, p=0.2), the mean values were lower than the mid-point of the scale (S1: 43.2; S8: 35.2), implying that the participants had not eaten to fullness. However, when asked if they could eat any more of the soup the values were also low on the scale, with no significant differences between S1 and S8 (21.5 compared to 30.2; t(75)=1.45, p=0.15).

There were no significant effects of gender (F(1,70)=0.02, p=0.89), soup flavour (F(1,70)=0.09, p=0.77), exposure group (whether the soup flavour had been exposed to MSG during the conditioning~~training~~ period) (F(1,70)=0.04, p=0.85), nor session (pre- or post conditioning~~training~~) (F(1,70)=1.63, p=0.21) on post-consumption satiety ratings and no significant interactions of any of the treatment effects. Similarly, there were no significant effects of gender (F(1,69)=0.03, p=0.87), soup flavour (F(1,69)=0.01, p=0.92),

exposure group (F(1,69)=2.08, p=0.15), nor session (F(1,69)=2.11, p=0.15) on the "could you eat more" rating and no significant interactions of any of the treatment effects.

Compliance and Comments

During the 6 day exposure period the participants were asked to note whether they ate the soups and to provide free-text comments. Of the 39 participants, 32 (82%) ate all of the soup provided on all days, 1 person forgot to eat the soup on one day, 5 participants ate only a quarter or half of the portion each day and one participant did not provide compliance information. Twenty-six participants (67%) commented that the soups were salty and of these comments 16 (41%) were specific to the soups containing MSG.

Consumption

Following the liking ratings, and prior to the consumption test, participants were asked to rate "how much could you eat of this soup now?". These ratings were below the mid-point on a 100 point scale (means: 40.5 and 38.1, across both soup flavours at S1 and S8). There were no significant effects of flavour (F(1,146)=2.29, p=0.13), session (F(1,146=0.31, p=0.58) , exposure group (F(1,146=1.72, p=0.19) or gender (F(1,146=0.48, p=0.49) on the expected consumption of the soup, and no significant interactions between these factors.

However, pairing with MSG over the conditioning sessions did lead to a significant effect on intake at the post-conditioning session. There was an increase in consumption of the soups between S1 and S8, but only in the condition ~~in which~~ where the soup had been previously paired with MSG (F(1,34) =6.34, p=0.017) (Figure 4). The mean consumption of soups which had been paired with MSG increased from 123 g at the pre-conditioning session to 164 g at the post conditioning session (standard error 24), whereas the consumption of soups not paired with MSG remained virtually constant (130 g and 121 g respectively).

There was a positive correlation between soup consumption across both sessions with liking (r=0.61, p<0.0001) and familiarity (r=0.29, p=0.009). However, there was no

correlation between consumption and rated hunger (r=0.13, p=0.24). There were no changes in consumption associated with soup flavour (F(1,34) =0.49, p=0.49) or gender (F(1,34) =0.69, p=0.41).

FIGURE 4 ABOUT HERE

Discussion

The major finding from this study is that repeat exposure to novel-flavoured soups with MSG increased consumption by older people after three at-home exposures. This finding is consistent with previous research that MSG can condition both appetite and consumption (Yeomans, Gould, et al., 2008). However, unexpectedly, the current data failed to show an increase in conditioned liking for the soup flavours. The failure to show an increase in hedonic ratings was consistent with the relatively low scores both pre- and post-conditioning for the question "would you choose this soup". The lack of increased liking following conditioning, contrary to expectations, is unlikely to be a function of the soup flavours themselves, novel though they were. Previous research has used highly novel, indeed somewhat unpalatable, flavours while still showing increased liking over repeat exposures, even without consumption (Prescott, 2004).

A more likely cause is the soups' salt content, an important determinant of the flavour acceptability of foods. In particular, appropriate salt levels are dependent on the context of the particular food (Sullivan & Birch, 1990). The average sodium level in UK soups is 224 mg/100ml (data taken from eight UK supermarket canned soups), which is comparable to the soup with no MSG used in this study (255 mg/100ml). However, we subsequently determined that the sodium level of the soup with 5% MSG was 983 mg per 100ml, so the 120 ml samples that were consumed provided 1180 mg sodium. We suggest, therefore, that the soups are highly likely to have been unpalatably salty. Comments received from many of the participants to the effect that some of the soups were too salty support this interpretation. Of course, the MSG- soups also failed to show changes in liking, but this may have reflected an entirely different mechanism, for example, insufficient exposure to

such flavour novelty.

Thus, although conditioned increases in consumption are most often accompanied by increases in liking (Yeomans, Gould, et al., 2008) these two processes were affected differently by the added MSG in this study. Effectively, this implies that FFL, the high ~~Na~~ sodium paired with the soup flavours, was acting to offset any conditioned liking that might have arisen as a result of pairing MSG with the flavour. In contrast, the ingested MSG paired with the flavour facilitated FNL, which provided the basis for conditioned increases in post-conditioning intake. In effect, we report here a serendipitous finding of conditioned intake in the absence of conditioned liking. As to whether this dissociation is a function of other aspects of the design apart from the high ~~Na~~ sodium content of the soups is not clear. Multiple exposures can in fact increase liking for a flavour that is initially unpalatable due to *low* ~~Na~~ sodium content (Methven, Langreney, et al., 2012), so the possibility exists that further exposure in this case may also have led to increased liking.

One interpretation of this dissociation is that it reflects separate processes inherent in the liking/wanting distinction. There are substantial difficulties in disentangling liking and wanting as reasons for intake, as both factors are likely to coincide most often (Havermans, 2011). Moreover, the learning processes behind each are likely to coincide. Thus, the results from Yeomans, Gould, et al. (2008) showed that pairing a flavour with an ingested nutrient such as glutamate under conditions of hunger produced both increased liking for the flavour and increased consumption of it. But conceptually, these two processes can be distinguished. As an illustration, a simple case in which they are dissociated might be where we would be willing to eat a food that was otherwise highly unpalatable if we were sufficiently hungry.

Of course, food intake can occur for a variety of reasons not associated with motivational states, including such cases as mindless eating (Braude & Stevenson, 2014). However, in the present study the increased intake was specifically associated with the addition of MSG to the soup. Moreover, other recent studies have provided evidence of liking/wanting

dissociation. Repeat exposure has been shown to lead to increased consumption of snack foods without subsequent increase of liking in the case of obese and non-obese women (Temple, et al., 2009). In the study conducted by Finlayson, King and Blundell (2007) they attempted to develop a methodology in order to dissociate wanting from liking and they also found that more differences in liking were observed when the participants were hungry than when satiated. These studies, plus the data from the present study, strongly indicate that, since motivation and liking can be dissociated, at least potentially, it is crucial to measure both phenomena.

Lastly, this research provides evidence that repeat exposure to novel foods with glutamate could result in increased appetite and consumption in older people. This is important for two reasons. Firstly, in these populations, under-nutrition is of particular concern, so strategies in increase food consumption are needed. Secondly, almost all studies on FFL and FNL have been conducted on young adults or children, and so there has been a need to establish that the same processes of learning occur in elderly populations, who may differ not only in their perceptual abilities but also particularly in their responses to novel foods (Meiselman, King, & Gillette, 2010). A previous study of a frail elderly population (Essed, van Staveren, Kok, & de Graaf, 2007) over a period of 16 weeks found no effect on rated pleasantness and measured consumption when 0.3% MSG was added to the animal protein part of a cooked meal. It may be that higher levels of MSG are required to trigger a change in consumption, perhaps due to post-ingestive effects. The concentration of MSG used in the present study was substantially higher than in previous studies, therefore, it remains to be determined whether lower levels (0.5 to 1%) are sufficient to trigger post-ingestive effects and increase food consumption.

In addition, while the volunteers participating in the present study were all older people, they were all healthy and none were reportedly underweight. It would be of benefit to further study frailer older adults at risk of under nutrition. For those in elderly care homes or elderly care wards in hospital, malnutrition is estimated to be 60% in those over 65 (Age Concern, 2006). Since the glutamate rather than the sodium was responsible for the increase wanting, the use of other sources of glutamate apart from MSG may be preferable

as a supplement to foods in such situations. The results may be generalizable to the use of natural food sources of glutamate and 5' ribonucleotides (Dermiki, et al., 2013; Dermiki, et al., 2014). Thus, our studies have shown that a combinations of natural ingredients can lead to higher umami taste in savoury meals than can be achieved by the addition of MSG alone (Dermiki, et al., 2013). Future work should focus on the longevity of this increase in appetite and consumption after MSG has been removed from the food. If the increase is completely due to FCL then constant addition of MSG may be required in food, since there is some evidence that such learning can extinguish (O'Sullivan, Alexander, Ferriday, & Brunstrom, 2010). However if FFL is important, especially in novel foods, then only a small number of exposures to MSG may be required, since such learning is thought to be permanent (Baeyens, Crombez, Bergh, & Eelen, 1988).

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Table 1: Design of the experiment (-MSG indicates no MSG added to soup, +MSG indicates 5% (w/w) MSG added to soup)

GROUP	*SESSION 1* *Pre-conditioning session*	*SESSIONS 2-7* *Conditioning sessions*	*SESSION 8* *Post-conditioning session*
Group 1	Liking and preference for Lemongrass AND Cumin **Group 1*a***: consumption Lemongrass **Group 1b**: consumption Cumin	This group consumed the following soups on alternate days: Lemongrass +MSG, Cumin –MSG	Liking and preference for Lemongrass AND Cumin **Group 1a**: consumption Lemongrass **Group 1b**: consumption Cumin
Group 2	Liking and preference for Lemongrass AND Cumin **Group 2*a***: consumption Lemongrass **Group 2b**: consumption Cumin	This group consumed the following soups on alternate days: Lemongrass -MSG, Cumin +MSG	Liking and preference for Lemongrass AND Cumin **Group 2a**: consumption Lemongrass **Group 2b**: consumption Cumin

Table ~~1~~2: Questions and anchors used in session 1 and 8 using unstructured 100mm line scales.

Question	**Anchors**
Would you choose to have this particular soup?	No, not at all – Yes, very much
How much could you eat now of this soup?	None at all – A lot
How familiar are you with the flavour of this soup?	Not at all – Very familiar
How hungry are you now?	Not at all – Extremely
How strong is your desire to eat?	Very weak – Very strong
How good is your mood?	Unpleasant – Pleasant
Do you feel satiated (are you full)?	Not at all – Extremely
Could you eat more of this particular soup?	Not at all – Yes, definitely

FIGURE CAPTIONS

Figure 1: Mean (+/- standard error) change in liking of soup flavours from session 1 to session 8 where participants had previously been exposed to the flavour with or without MSG (MSG+, MSG- respectively)

Figure 2: Mean (+/- standard error) change in familiarity ratings between session 1 and 8 for cumin and lemongrass in those previously exposed to the flavour with or without MSG (MSG+, MSG- respectively)

Figure 3: Mean (+/- standard error) ratings of hunger, desire to eat and mood, all pre- consumption, at sessions 1 and 8 (Ratings from Questions 4, 5 and 6 in Table ~~1~~2)

Figure 4: Mean (+/- standard error) consumption of soup in session 1 and session 8 where participants were either exposed to the flavour with MSG (MSG+) or exposed to the flavour without MSG (MSG-).