

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

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

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12

13 **Abstract**

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

28

29 **Highlights**

- 30
- 31 • Glutamate can condition increased food consumption in older adults
 - 32 • Older adults increased consumption of novel flavoured soups paired with glutamate
 - 33 • Older adults did not increase liking of novel flavoured soups paired with glutamate

33

34 **Keywords**

35 Conditioned liking, conditioned intake, wanting, consumption, glutamate

36 Introduction

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

53

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

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

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

69

70 Repeatedly pairing a novel soup flavour with ingested glutamate was found to produce a
71 substantially stronger preference than either simple repeated exposure to the soup flavour
72 or to the soup flavour paired with glutamate but ingested in only nominal amounts, a
73 condition equivalent to FFL (Prescott, 2004). In a subsequent study (Yeomans, Gould, et al.,
74 2008), conditioned flavour liking from ingested glutamate added to soups was also
75 observed. In addition, this later study also examined the impact of glutamate-conditioned
76 flavours on post-conditioning intake and hunger. Relative to a control condition in which
77 the soup did not contain added MSG, pairing with MSG produced a significant increase in
78 *ad-libitum* soup intake following conditioning. As well, tasting the soup whose flavour had
79 been paired with MSG increased ratings of hunger, again an effect not evident in the
80 control condition.

81

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

94

95 However, whereas obesity is of concern to the main stream western populations, the
96 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.

127

TABLE 1 ABOUT HERE

128

129 *Participants*

130 Forty volunteers (10 men, 30 women; 65- 88 years old, mean age: 73.7±5.5 years) were
131 recruited from a database of healthy older volunteers whom had previously stated an
132 interest in taking part in research studies. Each participant received a participant
133 information sheet and on agreeing to take part in the study they completed a consent
134 form. A screening questionnaire determined their eligibility to take part in the study;
135 exclusion criteria were the existence of relevant food allergies or intolerances, taking
136 medications known to affect appetite or taste and age under 65 years. The volunteers self-
137 reported height and weight, from which their BMI was calculated. The majority of
138 participants were in the healthy weight BMI category, the mean BMI was 23.7 kgm⁻², the
139 median was 23.1 kgm⁻², and the overall range was 18.6 to 31.9 kgm⁻². No volunteers were
140 reportedly underweight (<18.5 kgm⁻²), eight were in the overweight category (25 to 29.9
141 kgm⁻²) and two in the obese category (30 to 39.9 kgm²).

142

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

153

154 *Samples*

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

156 preparations, lemongrass and cumin (Treatt, Bury St Edmunds, UK) were added to create
157 the two different soup flavours. The soups were then processed in a canning retort at
158 121°C in either 400 ml or 120 ml cans, the larger size for the consumption tests and the
159 smaller sizes for the repeat exposure tastings. The particular flavours chosen were
160 considered novel for this age group and were used in order to avoid any effects of
161 familiarity on liking and consumption of the soups. All soups were prepared in the pilot
162 plant in University of Reading, following good manufacturing practices (GMP) and Hazard
163 Analysis Critical Control Points (HACCP). To half of the soup samples provided during the
164 [training conditioning](#) sessions (see below) 5% MSG w/w was added.

165

166 *Procedure*

167 *Pre-[training conditioning](#) session (session 1):* Volunteers tasted both of the two flavours of
168 soup and rated their liking for them on a standard 9-point hedonic category scale (1 =
169 dislike extremely and 9 = like extremely). They were also asked to [rank their](#)
170 [preference state which of the two samples they preferred](#). Soups were presented in a
171 balanced order and participants were asked to rinse their palate with water between
172 samples. Additional questions were asked on familiarity of each soup flavour as well as
173 questions on appetite and mood. These were rated using unstructured line scales (results
174 scaled 0-100) with anchors at both ends (Table 1). They were then presented one soup for
175 consumption. Each volunteer was asked to eat as much soup as they wanted; they were
176 provided with both a bowl of soup (250 ml) alongside an additional thermos flask of soup
177 (total amount of soup was 400ml). Consumption weight was calculated. Then participants
178 were asked further questions on appetite (Table [4-2](#) Q7-8).

179

180 *[Training Conditioning](#) sessions (Sessions 2 – 7):* The volunteers took home six cans of soup
181 (120 ml), three of each flavour, to consume on alternate days over the 6 days with one
182 flavour containing added MSG. Instructions were given to each volunteer on how to reheat
183 the soup and they were asked to consume one can of soup (120ml) at their normal lunch
184 time each day, recording the time they ate and any other comments on a chart provided.

185

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

195

196 | TABLE ~~1~~[2](#) ABOUT HERE

197

198 | *Statistical analysis*

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

206

207 | **Results**

208 | *Liking*

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

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

217

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

224

225 The scores for “would you choose this soup” were below the mid-point on a 100 point
226 scale (mean values of 37.8 and 35.6 across both soup flavours at S1 and S8, respectively).
227 There were no significant effects of flavour ($F(1,147)=2.59, p=0.11$), session ($F(1,147)=0.23,$
228 $p=0.63$), exposure group ($F(1,147)=1.14, p=0.29$) or gender ($F(1,147)=0.09, p=0.76$) on the
229 readiness to choose the soup, and no significant interactions between these factors.

230

231 FIGURE 1 ABOUT HERE

232 *Preference*

233 | ~~In neither S1 nor S8, was t~~ There was [no significant](#) difference in the number of subjects
234 who preferred [the cumin one soup](#) flavour [ed soup](#) over [another the lemongrass flavoured](#)
235 [soup in either S1 or S8](#) ($n=22$ cumin, $n=17$ lemongrass; at both sessions).

236

237 *Familiarity*

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

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

248

249 FIGURE 2 ABOUT HERE

250

251 *Appetite and Mood*

252 The participants pre-lunch hunger, desire to eat and mood ratings did not change
253 significantly between sessions (Figure 3) ($t(74)=0.93$, $p=0.35$; $t(74)=0.63$, $p=0.53$;
254 $t(74)=0.05$, $p=0.96$ respectively) . The mean hunger and desire to eat ratings were mid-
255 scale implying the participants were moderately hungry at the time of the tests, and the
256 mean mood rating was high implying the participants were in a pleasant mood.

257

258 FIGURE 3 ABOUT HERE

259

260 Although post consumption the overall mean satiety ratings were not higher in S8
261 compared to S1 ($t(76)=1.29$, $p=0.2$), the mean values were lower than the mid-point of the
262 scale (S1: 43.2; S8: 35.2), implying that the participants had not eaten to fullness. However,
263 when asked if they could eat any more of the soup the values were also low on the scale,
264 with no significant differences between S1 and S8 (21.5 compared to 30.2; $t(75)=1.45$,
265 $p=0.15$).

266

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

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

275

276 *Compliance and Comments*

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

283

284 *Consumption*

285 Following the liking ratings, and prior to the consumption test, participants were asked to
286 rate “how much could you eat of this soup now?”. These ratings were below the mid-point
287 on a 100 point scale (means: 40.5 and 38.1, across both soup flavours at S1 and S8). There
288 were no significant effects of flavour ($F(1,146)=2.29$, $p=0.13$), session ($F(1,146)=0.31$,
289 $p=0.58$), exposure group ($F(1,146)=1.72$, $p=0.19$) or gender ($F(1,146)=0.48$, $p=0.49$) on the
290 expected consumption of the soup, and no significant interactions between these factors.

291

292 However, pairing with MSG over the conditioning sessions did lead to a significant effect on
293 intake at the post-conditioning session. There was an increase in consumption of the soups
294 between S1 and S8, but only in the condition ~~in which~~ where the soup had been previously
295 paired with MSG ($F(1,34)=6.34$, $p=0.017$) (Figure 4). The mean consumption of soups
296 which had been paired with MSG increased from 123 g at the pre-conditioning session to
297 164 g at the post conditioning session (standard error 24), whereas the consumption of
298 soups not paired with MSG remained virtually constant (130 g and 121 g respectively).

299

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

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

305

306

FIGURE 4 ABOUT HERE

307

308 **Discussion**

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

320

321 A more likely cause is the soups’ salt content, an important determinant of the flavour
322 acceptability of foods. In particular, appropriate salt levels are dependent on the context of
323 the particular food (Sullivan & Birch, 1990). The average sodium level in UK soups is 224
324 mg/100ml (data taken from eight UK supermarket canned soups), which is comparable to
325 the soup with no MSG used in this study (255 mg/100ml). However, we subsequently
326 determined that the sodium level of the soup with 5% MSG was 983 mg per 100ml, so the
327 120 ml samples that were consumed provided 1180 mg sodium. We suggest, therefore,
328 that the soups are highly likely to have been unpalatably salty. Comments received from
329 many of the participants to the effect that some of the soups were too salty support this
330 interpretation. Of course, the MSG- soups also failed to show changes in liking, but this
331 may have reflected an entirely different mechanism, for example, insufficient exposure to

332 such flavour novelty.

333

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

346

347 One interpretation of this dissociation is that it reflects separate processes inherent in the
348 liking/wanting distinction. There are substantial difficulties in disentangling liking and
349 wanting as reasons for intake, as both factors are likely to coincide most often (Havermans,
350 2011). Moreover, the learning processes behind each are likely to coincide. Thus, the
351 results from Yeomans, Gould, et al. (2008) showed that pairing a flavour with an ingested
352 nutrient such as glutamate under conditions of hunger produced both increased liking for
353 the flavour and increased consumption of it. But conceptually, these two processes can be
354 distinguished. As an illustration, a simple case in which they are dissociated might be where
355 we would be willing to eat a food that was otherwise highly unpalatable if we were
356 sufficiently hungry.

357

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

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

370

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

386

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

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

404

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513

514

515 **Table 1:** Design of the experiment (-MSG indicates no MSG added to soup, +MSG indicates
 516 5% (w/w) MSG added to soup)
 517

<i>GROUP</i>	<i>SESSION 1</i> <i>Pre-conditioning session</i>	<i>SESSIONS 2-7</i> <i>Conditioning sessions</i>	<i>SESSION 8</i> <i>Post-conditioning session</i>
Group 1	Liking and preference for Lemongrass AND Cumin Group 1a: 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 2a: 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

518

519 **Table 12:** Questions and anchors used in session 1 and 8 using unstructured 100mm
 520 line scales.
 521

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

522

523

524 **FIGURE CAPTIONS**

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

528

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

532

533 Figure 3: Mean (+/- standard error) ratings of hunger, desire to eat and mood, all
534 pre- consumption, at sessions 1 and 8 (Ratings from Questions 4, 5 and 6 in Table [42](#))

535

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