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DOI:
[10.1016/j.appet.2022.106141](https://doi.org/10.1016/j.appet.2022.106141)

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Document Version
Peer reviewed version

Citation for published version (Harvard):
Ruddock, HK, Brunstrom, JM, Vartanian, LR & Higgs, S 2022, 'Social facilitation of energy intake in adult women is sustained over three days in a crossover laboratory experiment and is not compensated for under free-living conditions', *Appetite*, vol. 176, 106141. <https://doi.org/10.1016/j.appet.2022.106141>

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Social facilitation of energy intake in adult women is sustained over three days in a crossover laboratory experiment and is not compensated for under free-living conditions

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Pre-registration: The study methods and analysis plan were registered prior to analysis on the Open Science Framework website: Study 1 (<https://doi.org/10.17605/OSF.IO/HMABE>), Study 2 <https://doi.org/10.17605/OSF.IO/FA3PN>

Sources of support for the work

The research was funded by an Economic and Social Research Council grant awarded to SH, JB, and LV. Project reference: ES/P01027X/1.

This study was supported by the National Institute for Health and Care Research Bristol

Biomedical Research Centre. The views expressed are those of the

author(s) and not necessarily those of the NIHR or the Department of Health and Social Care

Running title; Sustained social facilitation of intake

Abstract

1
2 People eat more when they eat a meal with familiar others than they do when eating alone.
3 However, it is unknown whether eating socially impacts intake over the longer-term. The aim
4 of Study 1 was to examine whether socially facilitated intake is sustained across all meals and
5 across three consecutive days. The aim of Study 2 was to examine whether increased intake
6 during a social meal taken in the laboratory is compensated for under free-living conditions.
7 In Study 1, adult women ($n = 26$) ate all their meals across three days either with a friend or
8 alone in a counterbalanced cross-over design. In Study 2 adult women ($n = 63$) consumed a
9 meal in the laboratory either alone or with two friends and then recorded everything they ate
10 and drank for the next three days using electronic food diary software. In Study 1 intake
11 across 3 days was significantly greater in the Social ($M = 7310$ kcal, $SD = 1114$) than in the
12 Alone condition ($M = 6770$ kcal, $SD = 974$) ($F(1,423) = 16.10$, $p < .001$, $d = 0.51$). In Study
13 2 participants consumed significantly more in the laboratory when eating with their friends
14 ($M = 1209$ kcal, $SD = 340$) than when eating alone ($M = 962$ kcal, $SD = 301$) ($F(1,63) =$
15 13.28 , $p = .001$, $d = 0.77$). Analysis of food diary data plus laboratory intake showed that
16 intake remained significantly greater in the Social ($M = 6396$ kcal, $SD = 1470$) than in the
17 Alone condition after 4 days ($M = 5776$ kcal, $SD = 1182$) ($F(1,59) = 5.59$, $p = .021$, $d =$
18 0.05). These results show that social facilitation of eating is sustained over three days and
19 suggest that people fail to compensate for the social facilitation of eating.

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21 **Key words:** Social influences; Food intake; Compensation; Food diary; Laboratory study.

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Introduction

Food intake is strongly influenced by environmental cues. For example, people eat more when presented with a greater variety of foods (McCrorry et al., 1999) and when served a larger portion size (Rolls, Morris, & Roe, 2002). Another important, and yet often overlooked, external influence on food intake is social context. The mere act of eating socially exerts a particularly powerful influence on food intake (de Castro et al., 1990). Known as the ‘social facilitation of eating,’ research using food diaries, covert observation, and experimental manipulations have all shown that people eat more when eating with others, especially when eating with friends and family, relative to when dining alone (Ruddock, Brunstrom, Vartanian, & Higgs, 2019).

Although we see evidence that energy intake is influenced by environmental cues, almost all studies have focused on food intake at a single occasion. But what happens if the cue is presented over a longer period? Is the increase energy intake sustained over several days? Or does the effect wane over time? Even if the effect is sustained with repeated presentations of the cue, what happens in between eating occasions? Do people compensate for the effect of the cue by reducing their food intake in other meals? If they do, perhaps the net result is no overall increase in intake? Despite their importance, these questions remain largely unexplored. A rare exception can be found in the work of Rolls et al. (2006, 2007), who found that participants ate more when they were provided with larger portions, and that this pattern was sustained across all meals consumed over two (Rolls, Roe, & Meengs, 2006) and even 11 consecutive days (Rolls, Roe, & Meengs, 2007). These findings are important because they suggest that environmental cues may contribute to longer-term increases in energy intake which, over time, could contribute to weight gain and possibly to the development of obesity.

The social facilitation of intake is even larger than the effect of portion size (Ruddock et al., 2019) but it is unknown whether the effect is sustained over time and whether or not people compensate for socially facilitated intake. To find out whether the social facilitation of eating

50 affects energy intake over the longer-term, experimental research is required in which social
51 context is systematically manipulated in the laboratory. Examining the social facilitation of
52 eating under controlled conditions is important because it eliminates extraneous explanations
53 for such effects (e.g. differences in setting, portion sizes, etc.), and provides insight into the
54 *causal* relationship between social context and energy intake.

55 The aim of the current research was to examine whether the social facilitation of eating
56 is sustained over several days and whether people compensate for socially facilitated intake. In
57 Study 1, we tested the hypothesis that participants would eat more when eating with a friend,
58 relative to when eating alone, and that this effect would be sustained across breakfast, lunch,
59 and dinner, and across three consecutive days. In Study 2, we examined whether increased
60 intake during a social meal with friends was compensated for under free-living conditions.
61 Study 2 tested the hypothesis that participants who consume a social meal with friends in the
62 lab would eat more than participants who eat alone, and that this difference in intake would *not*
63 be compensated for by eating less at subsequent meals consumed within real-world settings.

64 **Study 1**

65 **Method**

66 **Participants**

67 Pairs of friends were recruited via social media and poster advertisements which were
68 placed around the University of Birmingham campus. Only female participants were
69 recruited to reduce error variance related to sex/gender differences in amounts consumed, and
70 because women eating with men is associated with reduced intake due to impression
71 management concerns (Brindal, Wilson, Mohr, & Wittert, 2015; Vartanian, 2015). Both men
72 and women have been observed to show social facilitation of intake (Ruddock et al., 2019).
73 The study was advertised as examining the effect of ‘time of day and group working on
74 problem solving ability’. Participants were eligible to take part if they met the following

75 criteria which were listed on the study advertisement: 1) were aged over 18 years, 2) were
76 occasional social eaters (1-3 meals per week), 3) had a self-reported BMI between 18-25
77 kg/m², 4) liked and were willing to eat the test foods, and 5) were willing to refrain from
78 consuming calorie-containing food and drinks outside of those provided during the study.
79 Participants were excluded if they were on any medication known to affect appetite, had been
80 diagnosed with an eating disorder, were regular smokers, were following a weight-loss diet,
81 were an athlete in training, were pregnant or breastfeeding, or had any food allergies or
82 intolerances. Using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007), we calculated that a
83 sample size of 26 participants was required to provide 80% power to detect medium-sized
84 main effects of eating condition (social versus alone) and interactions between condition and
85 day/meal type ($f=.30$) using a repeated-measures design ($\alpha = .05$). The findings from a
86 meta-analysis of the effects of social facilitation on eating (Ruddock et al., 2019) suggest a
87 large effect size but, given that it is unknown whether the effects are maintained over time,
88 we took a more conservative approach and predicted a medium effect size. Participants
89 received cash in exchange for taking part. The study methods and analysis plans were
90 registered after data collection but before analysis on the Open Science Framework website
91 (<https://doi.org/10.17605/OSF.IO/HMABE>). The study protocol was approved by the
92 University of Birmingham's Research Ethics Committee and was conducted in line with
93 ethical standards stated in the Declaration of Helsinki 1975.

94

95 **Design**

96 A within-subjects counter-balanced crossover design was used in which participants
97 attended two phases of 3 consecutive days (weekdays only). In one phase, participants
98 attended alone for 3 days and in the other phase they attended with a friend (also a
99 participant). The two 3-day phases were separated by a washout period of 14 days. The order

100 of Social versus Alone phase was randomly determined by the researcher (HR) using the
101 random integer generator available at: <https://www.random.org/integers/>.

102 **Measures**

103 *Three Factor Eating Questionnaire-18.*

104 The Three-Factor Eating Questionnaire Revised 18-item version (TFEQ-18) was
105 included to assess dietary behaviour (Karlsson, Persson, Sjöström, & Sullivan, 2000). The
106 instrument is a shortened and revised version of the original 51-item TFEQ (Stunkard &
107 Messick, 1985), and it comprises the following three subscales: 1) dietary restraint (i.e.
108 attempts to restrict food intake in order to control body weight; six items), 2) uncontrolled
109 eating (i.e. tendency to experience a loss of control over eating; nine items), and 3) emotional
110 eating (i.e. eating in response to negative moods; three items). In each case, a higher score
111 reflects a tendency to exhibit the associated construct.

112

113 *Food menus*

114 The three daily menus are presented in **Table 1**. The same meals were provided for
115 the Social and Alone conditions but the order of menus was randomised within phase. One
116 litre of water was provided at each meal. At breakfast, participants were offered a choice of
117 either tea or coffee, along with the option to add up to 50 ml of semi-skimmed milk and 15 g
118 of sugar. The amount of each food provided was fixed and so participants could not ask for
119 more of the individual foods. However, sufficient food was provided overall, such that
120 participants could not consume all of it (and none did).

121

122 **Procedure**

123 Testing took place between February 2019 and August 2019. All eligible participants
124 were tested. On each day, participants came to the eating behaviour laboratory at the
125 University of Birmingham for breakfast (between 8-10am), lunch (between 12-2pm), and

126 dinner (between 5-7pm), and were instructed to refrain from eating or drinking any calorie-
127 containing drinks, other than those provided during the test days. Meal timings were
128 scheduled to allow 4 hours between breakfast and lunch, and 5 hours between lunch and
129 dinner, and participants were free to leave the lab between meals. On each of the three days a
130 different menu was served, and the order of these menus was counterbalanced across
131 participants.

132 Before each meal, participants completed a short questionnaire in which they were
133 asked whether they had felt ill since their last meal, whether they had taken any medication
134 which may have affected their appetite, and whether they had consumed any other
135 foods/caloric beverages since their last meal. Participants who answered positively to the
136 latter question were asked to record a) what and how much they ate, b) the time that they ate,
137 c) where they ate, and c) how many people were present when they ate. Before breakfast,
138 participants were also asked to record the amount of time (in minutes) that they had spent
139 engaging in light, moderate, and vigorous activities in the past 24 hours. Before each meal,
140 participants completed hunger and fullness ratings (see supplementary materials for a
141 description of these measures).

142 Participants were then seated in a dining room (a room in the laboratory furnished with
143 a table/tablecloth, table lamp and dining chairs) either alone (Alone condition) or with their
144 friend (Social condition) and were provided with the meal which was laid out on the table. In
145 the Social condition, both participants were presented with the same foods, though each
146 participant had their own meal (i.e. they did not share a meal). Participants were invited to eat
147 as they normally would, i.e. communication was not prohibited, and were told they could eat
148 as much as they wished and to notify the experimenter once they had finished eating. The
149 researcher covertly recorded the duration of the meal (see supplementary materials), and food
150 intake was determined by covertly weighing foods before and after each meal. Following the
151 meal, participants completed measures of hunger and fullness, food liking, and mood (see

152 supplementary materials for a description of these measures). To reinforce the believability of
153 the cover story, participants were then given five minutes to complete a word- or number-
154 based problem-solving activity. They also completed a short questionnaire about how
155 difficult they found the activity, whether they thought the time of day had affected their
156 performance, and the strategy that they had used to complete the task with their friend (if
157 applicable).

158 At the end of the study (i.e. after dinner on day 3, phase 2), demand characteristics were
159 assessed by asking participants to write down what they thought were the aims of the study.
160 Measures of friendship closeness were also taken by asking participants how long they had
161 known their friend (in months), how well they think they know their friend (using a scale
162 ranging from 1 to 10 with anchor points 'Not very well' and 'Very well' respectively), and
163 how close they feel to their friend (1-10 scale with anchor points 'Not very close' and 'Very
164 close', respectively). Participants also indicated their age and ethnicity, and then completed
165 the TFEQ. Finally, the experimenter assessed the participant's height and weight, which was
166 used to calculate BMI, and participants were fully debriefed as to the true aims of the study.

167

168 **Data analysis**

169 For the main variable of interest (i.e. calorie intake), outlying values were identified
170 using Hoaglin and Iglewicz's (1987) outlier labelling rule. Six participants reported feeling ill
171 prior to at least 1 meal occasion, and one participant reported taking medication which may
172 affect appetite prior to two meal occasions (both social meals). However, the amount eaten
173 by these participants was within the normal range (i.e. none were identified as outliers) and
174 so their data was retained within subsequent analyses. Because observations were non-
175 independent (i.e. participants signed up to the study in pairs), data were analysed using a
176 multilevel model (MLM). Condition (i.e. Alone vs Social), condition order (i.e. Social first vs
177 Alone first), day (i.e. day 1, day 2, day 3), and meal (breakfast, lunch, and dinner) were

178 entered as fixed effects predictors of calorie intake. In the multi-level analyses, we planned to
179 include covariates in cases where a variable correlated significantly with the dependent
180 variable. Variables tested for correlations were age, BMI, and hunger. Statistical analyses
181 were conducted using SPSS version 27.0 (IBM Corp, 2020). For exploratory analyses of
182 effects of social context on food liking, appetite and mood change, see Supplementary
183 analyses.

184 Results

185 Participants

186 A total of 26 participants (13 friend pairs) took part in the study. Participant
187 characteristics are provided in **Table 2**. No participants guessed the true aims of the study.
188 The majority (n=21) confirmed that they had not eaten or consumed any calorie-containing
189 drinks, other than those provided to them, across the three days. Five participants reported
190 that they had consumed additional food on at least one occasion during the six test days. Of
191 these, two had consumed extra food during the Alone phase, two consumed additional food
192 during the Social phase, and one participant consumed additional food during both Social and
193 Alone conditions. Removal of these participants did not affect the overall findings and so
194 their data were included in the final analysis.

195 Initial inspection of the calorie intake data revealed one outlying value (295 kcal
196 consumed at lunch, day 1, Social condition). However, removing this datapoint had no
197 material impact on outcomes of the statistical analyses, and so the results are reported with
198 this datapoint included. Datapoints from one participant-pair (dinner, day 3, Social condition)
199 were removed due to a failure to follow instructions.

200 In support of our hypothesis, participants ate significantly more calories in the Social
201 condition (M=7310 kcal, SD=1114) relative to the Alone condition (M= 6770 kcal, SD=974),
202 $F(1,423)=16.10, p<.001, d=0.51$ (**Figure 1**). Figure 1 presents mean calories consumed as a
203 function of condition, day, and meal. There was also a main effect of day on food intake,

204 $F(2,423)=7.05$, $p<.001$, such that participants ate less on day 1 than on day 2 ($p=.008$) and
205 day 3 ($p<.001$). Calories consumed did not differ between days 2 and 3 ($p=.32$), and there
206 was neither a significant day \times condition interaction, $F(2,423)=0.08$, $p=.92$, nor a significant
207 meal type \times condition interaction, $F(2,423)=2.33$, $p=.098$.

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Interim discussion

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The results from Study 1 support our hypothesis that participants would eat more when eating with a friend than when eating alone, and that this effect would be sustained across breakfast, lunch, and dinner, as well as across three consecutive study days. This is important because it suggests that the social facilitation of eating persists across multiple meals, producing a sustained increase in energy intake over time.

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In Study 2, we build on these findings by examining whether participants compensate for the social facilitation of eating by reducing their energy intake at subsequent meals in a real-world setting. In Study 1, participants ate all their meals either socially or alone, and so it is unclear whether increased intake at a social meal might be offset by a reduction in intake at the next eating opportunity. Therefore, in Study 2 we examined self-reported free-living intake over four consecutive days immediately after participants had eaten a buffet lunch in the lab either alone (Alone condition) or with two friends (Social condition). In line with evidence of inadequate energy compensation following changes in energy intake (Levitsky, 2005; Levitsky et al., 2019), we hypothesised that participants in the Social condition would eat more than those in the Alone condition, and this would not be compensated for by eating less at subsequent meals.

227 **Study 2**

228 **Method**

229 **Participants**

230 Participants were recruited via social media and poster advertisements which were
231 placed around the University of Birmingham campus. Participants signed up to the study in
232 groups of three friends. As in Study 1, only female participants were recruited. The study was
233 advertised as examining the effect of ‘mood on eating behaviour.’ The inclusion/exclusion
234 criteria were the same as for Study 1 except that there was no requirement for participants to
235 refrain from eating anything outside of the lab. Using G*Power, and based on the results of
236 Study 1, we calculated that a sample size of 60 participants would be required to provide 80%
237 power to detect medium-sized main effects ($f=.37$) between the Social and Alone conditions
238 for total caloric intake ($\alpha = .05$) in a between-subjects design. We predicted a slightly
239 larger effect size for Study 2 because the participants are eating with 2 friends rather than 1 as
240 they did for Study 1 and social facilitation is known to be enhanced when there are more
241 people present (De Castro and Brewer 1992). Additional participants were recruited to
242 account for attrition. In total, 69 took part. The study method and analysis plan were
243 preregistered after data collection but prior to analysis on the Open Science Framework
244 website (<https://doi.org/10.17605/OSF.IO/FA3PN>). The study protocol was approved by the
245 University of Birmingham’s Research Ethics Committee and was conducted in line with
246 ethical standards stated in the Declaration of Helsinki 1975. All eligible participants were
247 tested.

248

249 **Design**

250 A between subjects (Social versus alone condition) design was used in which
251 participants took part in either the alone or social eating condition and then completed a food
252 diary for the remainder of that day and the next three days. As participants signed up for the

253 study as a group of three friends, each trio was randomly allocated to either the Alone or
254 Social condition by the researcher (HR) using the random integer generator available at:
255 <https://www.random.org/integers/>. Participants in the Alone condition ate the buffet lunch in
256 the laboratory alone, while those in the Social condition ate the same buffet with their two
257 friends.

258

259 **Materials**

260 *Buffet lunch*

261 Participants were provided with a buffet lunch comprising 1952 kcal. **Table 3**
262 provides a full list of foods provided to each participant. The amount of each food provided
263 was fixed and so participants could not ask for more of the individual foods. However,
264 sufficient food was provided overall, such that participants could not consume all of it (and
265 none did).

266

267 *Food diary*

268 Participants used Myfood24 software (2016) to record everything that they ate and
269 drank for the 4 days following their initial lab session. MyFood24 is a 24-hour dietary recall
270 tool that provides a valid and user-friendly measure of food intake (Carter et al., 2015; Wark
271 et al., 2018). After each eating episode (breakfast, lunch, dinner, and snacks), participants
272 recorded the foods and drinks consumed, and their respective portion size. To minimise
273 under-reporting, Myfood24 also includes prompts for commonly forgotten foods, and
274 participants are asked to review their diary before submitting it. The output is generated by
275 drawing on a nutritional information database of 40,274 food items and it provides a
276 summary of daily calories consumed by each participant. After submitting a food diary,
277 participants were automatically directed to a follow-up questionnaire (using Qualtrics
278 software) in which they were asked to record how many people they ate with during each

279 meal or snack. If participants indicated that they had eaten a meal or snack with one or more
280 people, they were asked to record how well they knew each person. Specifically, for each
281 individual at the meal, they indicated whether the person was a friend, a family member, a
282 romantic partner, an acquaintance, or a stranger. To obscure the true purpose of the study,
283 and consistent with the cover story, participants were then asked to choose words that
284 described their mood during each meal or snack (i.e. happy, angry, annoyed, sad/depressed,
285 excited, content, anxious).

286 **Procedure**

287 Testing took place between October 2019 and February 2020, and in the same room as
288 in Study 1. Participants were invited to attend the Eating behaviour laboratory at the
289 University of Birmingham between 12-2pm (to coincide with normal lunch hours), and were
290 instructed to refrain from eating or drinking any calorie-containing drinks for at least three
291 hours before the start of their session. Participants arrived at the lab with their two friends.

292 Before the meal, participants completed VAS measures of hunger and fullness, and
293 then completed a measure of food cravings (see supplementary materials for descriptions of
294 these measures). They were then offered the buffet lunch and were instructed to eat as much
295 as they wished. Food was laid out on a table and each participant was given their own buffet
296 (i.e. friends did not share). Participants were invited to eat as they normally would, i.e.
297 communication was not prohibited, and they were told they could eat as much as they wished
298 and to notify the experimenter once they had finished eating. Meal duration was recorded
299 covertly, and foods were weighed covertly before and after eating to determine food intake.
300 Following the meal, participants were placed in separate rooms and completed VAS
301 measures of appetite, food liking, mood, and overall meal enjoyment (see supplementary
302 materials).

303 After completing the questionnaires, participants were shown how to record their food
304 intake using the Myfood24 software. They were instructed to record everything that they ate
305 and drank for the remainder of that day (day 1), and for three subsequent days (days 2-4).

306 Alcohol and non-alcoholic drinks were recorded but due to the high social intake of
307 alcohol in this population we analysed the data with and without calories from alcohol.

308 Between five and 14 days following the first lab session, participants returned to the lab to
309 complete the following assessments: 1) demand characteristics were assessed by asking
310 participants to write down what they thought the aims of the study were; 2) dietary restraint,
311 uncontrolled eating, and emotional eating, were assessed using the TFEQ-18 (Karlsson et al.,
312 2000) (described in Study 1); 3) friendship familiarity was assessed by asking participants to
313 write down how long they have known each of the friends with whom they had participated
314 (open ended question), and how well they felt they know these friends (1-10 scale anchored
315 by 'Not very well' and 'Very well', respectively); and 4) other demographics, including age
316 and ethnicity. Height and weight were then measured by the researcher to calculate BMI, and
317 participants were fully debriefed as to the true aims of the study.

318

319 **Data analysis**

320 For the main variables of interest (calorie intakes in the lab and across days), outlying
321 values were identified using Hoaglin and Iglewicz's (1987) outlier labelling rule. Because
322 observations are non-independent (i.e. participants signed up to the study in groups of three),
323 data were analysed using MLMs. In three separate analyses, Condition (Alone vs Social) was
324 entered as a fixed-effects predictor of food consumed (kcal) during the lab session, of total
325 intake (kcal) at the end of day 1 (lab intake + food diary intake for day 1) and of total intake
326 at the end of day 4 (lab intake + food diary intake for days 1 to 4). Potential covariates were
327 entered into a bivariate correlation matrix with the dependent variables. Variables that were

328 significantly correlated with a dependent variable were included as covariates in the multi-
329 level analyses. Statistical analyses were conducted using SPSS version 27.0 (IBM, 2020).

330

331

Results

332 Initial data checks

333 Initial inspection of the data revealed that calorie intake on day 1 (food diary data) was
334 not normally distributed (skewness=3.02, SE=0.29; kurtosis=15.06, SE=0.58). Using Hoaglin
335 and Iglewicz's (1987) outlier labelling rule, two participants were identified as outliers,
336 having consumed over 1837 kcal on day 1 *after* the lab session (i.e. *not* including calories
337 consumed within the lab or before lunch). Removing these participants corrected the
338 distribution, and they were therefore excluded from subsequent analyses. No participants
339 correctly guessed the aim of the study. Initial inspection of the data revealed that BMI
340 correlated positively with the amount consumed during the lab session, $r=.283$, $p=.021$, total
341 day 1 intake (i.e. lab intake + food diary intake for day 1), $r=.322$, $p=.009$, and total intake
342 across all four days, $r=.383$, $p=.002$. BMI was therefore included as a covariate in the main
343 analyses.

344

345 Participants

346 Participant characteristics are shown in **Table 4**. A MANOVA revealed no between-
347 condition differences in the participants' age, BMI, TFEQ-subscale scores, or friendship
348 familiarity, $F(6,59)=0.63$, $p=.630$. MLM analyses also revealed no differences between
349 conditions on appetite ratings prior to the meal, $F(1,65)=0.24$, $p=.623$ (Social: $M=78.1$
350 $SD=13.1$; Alone: 76.6 , $SD=12.0$).

351

352 Effect of condition on food intake in the lab

353 The MLM revealed a significant effect of condition on food intake, $F(1,63)=13.28$,
354 $p=.001$, $d=0.77$, such that participants in the Social condition consumed significantly more
355 calories than did those in the Alone condition (Social: $M=1209$ kcal, $SD=340$; Alone: $M=962$
356 kcal, $SD=301$).

357

358 Effect of condition on day 1 intake

359 Food diary data for day 1 were obtained from 65 participants (Alone $n=33$; Social
360 $n=32$). There was a significant effect of condition on day 1 total intake, $F(1,61)=5.79$,
361 $p=.019$, $d=0.50$. Participants consumed significantly more in the Social condition ($M=1990$
362 kcal, $SD=468$) than in the Alone condition ($M=1756$ kcal, $SD=460$). This result did not
363 change when adding calories from alcohol (Social: $M=2080$ kcal, $SD=525$; Alone: $M=1845$
364 kcal, $SD=482$; $F(1,61)=4.37$, $p=.041$).

365 Further analyses revealed that there were no between-condition differences in calories
366 consumed *after* the lab session on day 1, $F(1, 61)=0.03$, $p=.875$, or the number of meals eaten
367 socially $F(1,65)=0.24$, $p=.877$. These findings are important because they suggest that the
368 difference in total calorie intake at the end of day 1 was due to differences in intake that
369 occurred during the lab meal.

370

371 Effect of condition on total four-day calorie intake

372 Total four-day intake (i.e. lab calories + *all* food diary data) was obtained from 63
373 participants (Alone $n=31$; Social $n=32$). Participants in the Social condition consumed
374 significantly more calories over the four days than did those in the Alone condition (Social:
375 $M=6396$ kcal, $SD=1470$; Alone: $M=5776$ kcal, $SD=1182$), $F(1,59)=5.59$, $p=.021$, $d=0.46$.
376 This result did not change when adding calories from alcohol (Social: $M=6712$ kcal,
377 $SD=1600$; Alone: $M=5980$ kcal, $SD=1228$; $F(1,59)=6.33$, $p=.015$).

378 Removing the food consumed during the lab session showed that the amount consumed
379 during the four days *following* the lab session did not differ between conditions,
380 $F(1,59)=2.32, p=.133$, and there were no between-condition differences in the number of
381 meals that were consumed socially after the lab session, $F(1,64)=0.30, p=.589$. These
382 findings suggest that participants in the Social condition did not compensate for additional
383 food consumed during the lab session by eating less over subsequent meals (see **Figure 2**).

384

385

Discussion

386 Across two controlled studies, we provide the first evidence that the social facilitation
387 of eating is sustained across several days (Study 1), and that people fail to compensate for
388 additional calories consumed during social meals under free-living conditions (Study 2). In
389 Study 1, across three consecutive days, participants consumed an additional 539 kcal when
390 they ate all their meals with a friend (relative to eating alone). These findings were extended
391 in Study 2, in which we examined whether participants would compensate for the social
392 facilitated increase in energy intake in the lab by reducing their energy intake at subsequent
393 real-world meals. Those who ate a social meal in the lab consumed a larger lunch (additional
394 247 calories) than did those who ate alone, and there was no evidence for compensation
395 across the following four days. Together, the findings from Studies 1 and 2 suggest that the
396 social facilitation of eating is sustained over time and that people fail to compensate for the
397 social facilitation of eating. These findings are important because they suggest that eating
398 socially may lead to greater energy intake over the longer-term. On average social meals
399 were around 150 calories larger than non-social meals. For a woman with an average height
400 and weight, relative to eating alone, consuming one social meal per day could result in weight
401 gain of around 4 kg over a year (Hall et al., 2011).

402

403

By experimentally manipulating social context, we can rule out other explanations for
the social facilitation of eating (e.g. differences in the type of food available, context, etc.)

404 and show that eating socially has a *causal* effect on energy intake, which persisted over
405 several days. Our findings are also consistent with research demonstrating sustained effects
406 of other environmental cues (i.e. portion size) on intake (Rolls et al., 2006, 2007). Together,
407 these findings provide further support for the idea that at least over a period of days,
408 stimulation of intake by external factors does not induce active regulatory appetite
409 mechanisms to counteract increased consumption (Levitsky, 2005; Levitsky et al., 2019), and
410 that day-to-day intake is not under tight biological regulation (Casanova, Finlayson, Blundell,
411 & Hopkins, 2019).

412 Evidence for the persistent effects of social context on intake over several days is
413 consistent with the idea that the social facilitation of eating may be a hard-wired
414 psychological phenomenon. Indeed, evidence for the social facilitation of eating has been
415 observed across a range of non-human animals (Forkman, 1991; Harlow & Yudin, 1933;
416 Rajecki, Kidd, Wilder, & Jaeger, 1975; Tolman, 1964), suggesting that it may serve an
417 important evolutionary purpose. As we have discussed in detail elsewhere (Ruddock et al.,
418 2019), one possibility is that the social facilitation of eating evolved as a strategy to ensure
419 that we obtain maximum personal resources while sharing limited food resources with other
420 group members.

421 There are implications of the present results for healthy eating and nutritional
422 interventions. Social eating might be used to increase the food intake of undernourished
423 populations e.g. elderly people with reduced appetite. People who wish to avoid overeating,
424 might wish to develop strategies that allow them to experience the benefits of social eating
425 (Dunbar, 2017) while at the same time mitigating the effects of social context on excess
426 calorie intake. One strategy may be to actively compensate for socially facilitated food intake
427 by eating smaller meals before or after a social meal. Another strategy may be to advise
428 people to plan their meal in advance of a social occasion. Indeed, in a recent study (Ruddock,
429 Long, Brunstrom, Vartanian, & Higgs, 2021) we found that participants who served

430 themselves *before* eating with a friend consumed significantly fewer calories than those who
431 served themselves *during* the meal. Thus, pre-ordering food or serving oneself before the
432 start of a meal, may help people to avoid unintentionally overeating during social meals.

433 A strength of the present studies is that we examined food intake within laboratory-
434 and real-world settings, and so we were able to establish the *causal* effect of social eating on
435 longer-term calorie intake, while maximising the applicability of our findings to real-world
436 contexts. A further methodological strength was that food intake was monitored for several
437 days after a social meal (Study 2). The results also suggest that laboratory-based
438 demonstrations of the social facilitation of eating are unlikely to be explained by the novelty
439 of eating with a friend in a context in which free food is available, because such an effect
440 might be expected to wear off over time.

441 A limitation of the present studies is that we did not measure energy expenditure and
442 so we cannot rule out the possibility that participants compensated for additional calorie
443 intake by expending more energy. In Study 1, participants recorded the amount of time that
444 they had spent engaging in light, moderate, and vigorous exercise during the 24 hours prior to
445 each test day. Analysis of these data revealed no significant main effect of condition (Alone
446 vs Social) on exercise duration, suggesting that participants did not compensate for socially
447 facilitated food intake by engaging in more physical activity (see supplementary materials).
448 However, future research could incorporate other more precise measures of energy
449 expenditure (such as actigraphy). In addition, recruitment was restricted to women with a
450 BMI within the normal weight range. It is therefore important for future research to establish
451 the generalisability of our findings to other populations. To date there has been no systematic
452 study of the moderating effects of weight status and/or sex/gender on social facilitation of
453 eating. However data from self-report and observational studies indicate that people with
454 overweight may show a weaker effect, perhaps because concerns about portraying a

455 particular impression to others overrides social facilitation effects in these contexts (Salvy, de
456 la Haye, Bowker, & Hermans, 2012).

457 To conclude, our findings provide compelling evidence that the social facilitation of
458 eating leads to an uncompensated increase in intake that is sustained over several days.
459 Future research should establish the extent to which social eating contributes to weight gain
460 and to develop strategies to help people manage social eating situations to allow them to
461 reach their health goals.

462

463 **Acknowledgments**

464 myfood24 was developed through Medical Research Council funding, grant G110235.

465 myfood24 is now being supported by spinout company Dietary Assessment Ltd. Requests to
466 use myfood24 should be made to enquiries@myfood24.org.

467

468 We thank following students for assistance with the data collection: Elaina Dudley, Keira
469 Perks, Milene Fernandes, Sarah Miller, Harriet Abbot, Arielle Kaufman (Study 1) and
470 Xuebing Huang, Jinyu Liu, Ilayda Yondem, Macarena Perales, Georgina Hobden, Emma
471 Williams, Cerys Cherry (Study 2).

472

473 **Conflict of Interest and Funding Disclosure**

474 Helen K. Ruddock “no conflicts of interest.”

475 Jeff M. Brunstrom “no conflicts of interest.”

476 Lenny R. Vartanian “no conflicts of interest.”

477 Suzanne Higgs “no conflicts of interest.”

478

479 **Author Contributions**

480 SH, JB, LV & HR designed the research. Testing and data collection were performed by HR.

481 HR performed the data analyses. SH, JB, LV & HR wrote the paper. All authors approved the

482 final version of the manuscript for submission. SH had primary responsibility for final
483 content.

484

485 **Data Sharing.**

486 Data described in the manuscript will be made publicly and freely available without
487 restriction at <https://reshare.ukdataservice.ac.uk/>.

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573

574

Figure legends

575 *Figure 1.* Mean calories consumed as a function of meal, day, and condition. Error bars

576 represent the standard error of the mean.

577

578 *Figure 2.* Mean calories consumed as a function of condition and day. Error bars represent

579 the standard error of the mean.

580

581 Table 1. *Foods provided and calorie information for each of the three daily menus.*

	Menu 1 (total kcal= 3589)	Menu 2 (total kcal = 3699)	Menu 3 (total kcal = 3843)
Breakfast	<ul style="list-style-type: none"> • 2 x wholemeal toast with 40 g hazelnut chocolate spread (433 kcal) • 150 g strawberry yogurt (123 kcal) • 207 g canned fruit with juice (101 kcal) • 150 g orange juice (70 kcal) 	<ul style="list-style-type: none"> • Bagel with 60 g soft cheese spread (425 kcal) • 150 g strawberry yogurt (123 kcal) • 207 g canned fruit with juice (101 kcal) • 150 g orange juice (70 kcal) 	<ul style="list-style-type: none"> • 80 g granola (353 kcal) • 200 g semi-skimmed milk (100 kcal) • 150 g strawberry yogurt (123 kcal) • 207 g canned fruit with juice (101 kcal) • 150 g orange juice (70 kcal)
	kcal = 727	kcal = 719	kcal = 747
Lunch	<ul style="list-style-type: none"> • 200 g cheese & onion quiche (521 kcal) • 150 g new potatoes (114 kcal) • 35 g green salad (8 kcal) • 75 g brownie bites (291 kcal) • 50 g salted crisps (272 kcal)¹ 	<ul style="list-style-type: none"> • 2 x bean burgers (458 kcal) • White bread roll with 10 g margarine (247 kcal) • 60 g millionaire bites (300 kcal) • 70 g cheese tortilla chips (349 kcal) 	<ul style="list-style-type: none"> • Cheese sandwich comprising 3 pieces of wholemeal bread, 20 g margarine, 60 g cheddar cheese (742 kcal) • 70 g flapjack bites (313 kcal)² • 50 g salt & pepper crisps (311 kcal)¹
	kcal = 1206	kcal = 1354	kcal = 1366
Dinner	<ul style="list-style-type: none"> • 100 g (uncooked weight) pasta mixed with 250 g tomato pasta sauce, 30 g cheddar cheese (580 kcal) • 200 g tiramisu (500 kcal) • 110 g milk chocolate buttons (576 kcal) 	<ul style="list-style-type: none"> • 300 g cheese & tomato pizza (767 kcal) • 35 g salad (8 kcal) • 200 g chocolate dessert (270 kcal) • 110 g milk chocolate pieces (581 kcal) 	<ul style="list-style-type: none"> • 450 g vegetarian lasagne (408 kcal) • 200 g (frozen weight) chips (358 kcal) • 150 g strawberry cheesecake (416 kcal) • 110 g milk chocolate (548 kcal)
	kcal = 1656	kcal = 1626	kcal = 1730

582 UK to US translation: ¹Chips; ²Oat bars

583

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585

586 Table 2. *Participant characteristics in Study 1*

	Mean (SD)
Age (years)	20.8(2.8)
BMI (kg/m ²)	23.0(2.9)
TFEQ-restraint	14.1(4.0)
TFEQ-uncontrolled	22.9(4.7)
TFEQ-Emotional	7.2(2.4)
Friendship duration (months)	21.1(29.4)
Friendship 'How well'*	8.1(1.7)
Friendship 'How close'†	8.0(1.8)

587

* On a scale of 1-10 (with anchor points 'Not very well' and 'Very well', respectively), how well do you think you know your friend?

588

† On a scale of 1-10 (with anchor points 'Not very close' and 'Very close', respectively), how close do you feel you are with your friend?

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592

593 Table 3. *Foods provided during the buffet lunch (per participant) in Study 2.*

	Portion size (g)	kcal
Tesco cheese & onion quiche	200	524
Tesco salted crisps¹	25	136
Cadburys dairy milk chocolate buttons	60	321
Tesco stuffed crust cheese pizza	215	550
Brownies	50	192
Flapjacks²	50	224

594 UK to US translation: ¹Chips; ²Oat bars

595

596

597

598

599 Table 4. *Participant characteristics in Study 2.*

	Alone condition (n=34)	Social condition (n=33)	Univariate test statistic
	Mean (SD)	Mean (SD)	
Age (years)	19.4(1.1)	19.4(1.1)	F(1,64)=0.01, p=.911
BMI (kg/m ²)	22.4(2.9)	21.7(2.5)	F(1,64)=1.04, p=.311
TFEQ-restraint	12.7(3.9)	13.5(2.8)	F(1,64)=0.88, p=.351
TFEQ-uncontrolled	22.4(4.1)	22.2(3.2)	F(1,64)=0.07, p=.788
TFEQ-Emotional	7.9(1.7)	7.9(2.2)	F(1,64)=0.00, p=.999
Familiarity*	7.2(1.6)	7.5(2.1)	F(1,64)=0.25, p=.620

600

601

* On a scale of 1-10 (with anchor points 'Not very well' and 'Very well', respectively), how well do you think you know your friend?

602