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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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ABSTRACT

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

1. Introduction

Food intake is strongly influenced by environmental cues. For example, people eat more when presented with a greater variety of foods (McCrory 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, Brewer, Elmore, & Orozco, 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, Roe, and Meengs (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 et al., 2006) and even 11 consecutive days (Rolls, Roe, & Meengs, 2007). These findings are

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

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

2. Study 1

2.1. Method

2.1.1. Participants

Pairs of friends were recruited via social media and poster advertisements which were placed around the University of Birmingham campus. Only female participants were recruited to reduce error variance related to sex/gender differences in amounts consumed, and because women eating with men is associated with reduced intake due to impression management concerns (Brindal, Wilson, Mohr, & Wittert, 2015; Vartanian, 2015). Both men and women have been observed to show social facilitation of intake (Ruddock et al., 2019). The study was advertised as examining the effect of 'time of day and group working on problem solving ability'. Participants were eligible to take part if they met the following criteria which were listed on the study advertisement: 1) were aged over 18 years, 2) were occasional social eaters (1–3 meals per week), 3) had a self-reported BMI between 18 and 25 kg/m^2, 4) liked and were willing to eat the test foods, and 5) were willing to refrain from consuming calorie-containing food and drinks outside of those provided during the study. Participants were excluded if they were on any medication known to affect appetite, had been diagnosed with an eating disorder, were regular smokers, were following a weight-loss diet, were an athlete in training, were pregnant or breastfeeding, or had any food allergies or intolerances. Using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007), we calculated that a sample size of 26 participants was required to provide 80% power to detect medium-sized main effects of eating condition (Social versus Alone) and interactions between condition and day/meal type (f = 0.30) using a repeated-measures design (alpha = .05). The findings from a meta-analysis of the effects of social facilitation on eating (Ruddock et al., 2019) suggest a large effect size but, given that it is unknown whether the effects are maintained over time, we took a more conservative approach and predicted a medium effect size. Participants received cash in exchange for taking part. The study methods and analysis plans were registered after data collection but before analysis on the Open Science Framework website (https://doi.org/10.17605/OSF.IO/HMABE). The study protocol was approved by the University of Birmingham's Research Ethics Committee and was conducted in line with ethical standards stated in the Declaration of Helsinki 1975.

2.1.2. Design

A within-subjects counter-balanced crossover design was used in which participants attended two phases of 3 consecutive days (weekdays only). In one phase, participants attended alone for 3 days and in the other phase they attended with a friend (also a participant). The two 3-day phases were separated by a washout period of 14 days. The order of Social versus Alone phase was randomly determined by the researcher (HR) using the random integer generator available at: https://www.random.org/integers/.

2.1.3. Measures

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

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	• 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) kcal = 727	• 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) kcal = 719	• 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 = 747
Lunch	• 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] kcal = 1206	• 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) kcal = 1354	• 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 = 1366
Dinner	• 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) kcal = 1656	• 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) kcal = 1626	• 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 = 1730

UK to US translation: [1]Chips; [2]Oat bars.

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

2.1.4. Procedure

Testing took place between February 2019 and August 2019. All eligible participants were tested. On each day, participants came to the eating behaviour laboratory at the University of Birmingham for breakfast (between 8 and 10am), lunch (between 12 and 2pm), and dinner (between 5 and 7pm), and were instructed to refrain from eating or drinking any calorie-containing drinks, other than those provided during the test days. Meal timings were scheduled to allow 4 h between breakfast and lunch, and 5 h between lunch and dinner, and participants were free to leave the lab between meals. On each of the three days a different menu was served, and the order of these menus was counterbalanced across participants.

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

Participants were then seated in a dining room (a room in the laboratory furnished with a table/tablecloth, table lamp and dining chairs) either alone (Alone condition) or with their friend (Social condition) and were provided with the meal which was laid out on the table. In the Social condition, both participants were presented with the same foods, though each participant had their own meal (i.e. they did not share a meal). Participants were invited to eat as they normally would, i.e. communication was not prohibited, and were told they could eat as much as they wished and to notify the experimenter once they had finished eating. The researcher covertly recorded the duration of the meal (see supplementary materials), and food intake was determined by covertly weighing foods before and after each meal. Following the meal, participants completed measures of hunger and fullness, food liking, and mood (see supplementary materials for a description of these measures). To reinforce the believability of the cover story, participants were then given 5 min to complete a word- or number-based problem-solving activity. They also completed a short questionnaire about how difficult they found the activity, whether they thought the time of day had affected their performance, and the strategy that they had used to complete the task with their friend (if applicable).

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

2.1.5. Data analysis

For the main variable of interest (i.e. calorie intake), outlying values were identified using Hoaglin and Iglewicz's (1987) outlier labelling rule. Six participants reported feeling ill prior to at least 1 meal occasion, and one participant reported taking medication which may affect appetite prior to two meal occasions (both social meals). However, the amount eaten by these participants was within the normal range (i.e. none were identified as outliers) and so their data was retained within subsequent analyses. Because observations were non-independent (i.e. participants signed up to the study in pairs), data were analysed using a multilevel model (MLM). Condition (i.e. Alone vs Social), condition order (i.e. Social first vs Alone first), day (i.e. day 1, day 2, day 3), and meal (breakfast, lunch, and dinner) were entered as fixed effects predictors of calorie intake. In the multi-level analyses, we planned to include covariates in cases where a variable correlated significantly with the dependent variable. Variables tested for correlations were age, BMI, and hunger. Statistical analyses were conducted using SPSS version 27.0 (IBM Corp, 2020). For exploratory analyses of effects of social context on food liking, appetite and mood change, see Supplementary analyses.

2.2. Results

2.2.1. Participants

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

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

In support of our hypothesis, participants ate significantly more calories in the Social condition (M = 7310 kcal, SD = 1114) relative to the Alone condition (M = 6770 kcal, SD = 974), $F(1,423) = 16.10$, $p < .001$, $d = 0.51$. Fig. 1 presents mean calories consumed as a function of condition, day, and meal. There was also a main effect of day on food intake, $F(2,423) = 7.05$, $p < .001$, such that participants ate less on day 1 than on day 2 ($p = .008$) and day 3 ($p < .001$). Calories consumed did not differ between days 2 and 3 ($p = .32$), and there was neither a significant day × condition interaction, $F(2,423) = 0.08$, $p = .92$, nor a significant meal type × condition interaction, $F(2,423) = 2.33$, $p = .098$.

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'[a]	8.1(1.7)
Friendship 'How close'[b]	8.0(1.8)

[a] 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?.
[b] 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?.

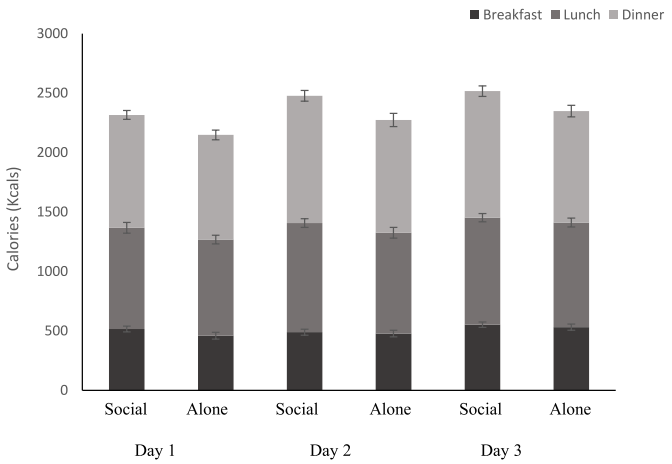

Fig. 1. Mean calories consumed as a function of meal, day, and condition. Error bars represent the standard error of the mean.

2.3. Interim discussion

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.

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.

3. Study 2

3.1. Method

3.1.1. Participants

Participants were recruited via social media and poster advertisements which were placed around the University of Birmingham campus. Participants signed up to the study in groups of three friends. As in Study 1, only female participants were recruited. The study was advertised as examining the effect of 'mood on eating behaviour.' The inclusion/exclusion criteria were the same as for Study 1 except that there was no requirement for participants to refrain from eating anything outside of the lab. Using G*Power, and based on the results of Study 1, we calculated that a sample size of 60 participants would be required to provide 80% power to detect medium-sized main effects (f = 0.37) between the Social and Alone conditions for total caloric intake (alpha = .05) in a between-subjects design. We predicted a slightly larger effect size for Study 2 because the participants are eating with 2 friends rather than 1 as they did for Study 1 and social facilitation is known to be enhanced when there are more people present (De Castro & Brewer, 1992). Additional participants were recruited to account for attrition. In total, 69 took part. The study method and analysis plan were preregistered after data collection but prior to analysis on the Open Science Framework website (https://doi.org/10.17605/OSF.IO/FA3PN). The study protocol was approved by the University of Birmingham's Research Ethics Committee and was conducted in line with ethical standards stated in the Declaration of Helsinki 1975. All eligible participants were tested.

3.1.2. Design

A between subjects (Social versus Alone condition) design was used in which participants took part in either the alone or social eating condition and then completed a food diary for the remainder of that day and the next three days. As participants signed up for the study as a group of three friends, each trio was randomly allocated to either the Alone or Social condition by the researcher (HR) using the random integer generator available at: https://www.random.org/integers/. Participants in the Alone condition ate from the buffet lunch in the laboratory alone, while those in the Social condition ate from the same buffet with their two friends.

3.1.3. Materials

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

3.1.3.2. Food diary. Participants used Myfood24 software (2016) to record everything that they ate and drank for the 4 days following their initial lab session. MyFood24 is a 24-h dietary recall tool that provides a valid and user-friendly measure of food intake (Carter et al., 2015; Wark et al., 2018). After each eating episode (breakfast, lunch, dinner, and snacks), participants recorded the foods and drinks consumed, and their respective portion size. To minimise under-reporting, Myfood24 also includes prompts for commonly forgotten foods, and participants are asked to review their diary before submitting it. The output is generated by drawing on a nutritional information database of 40,274 food items and it provides a summary of daily calories consumed by each participant. After submitting a food diary, participants were automatically directed to a follow-up questionnaire (using Qualtrics software) in which they were asked to record how many people they ate with during each meal or snack. If participants indicated that they had eaten a meal or snack with one or more people, they were asked to record how well they knew each person. Specifically, for each individual at the meal, they indicated whether the person was a friend, a family member, a romantic partner, an acquaintance, or a stranger. To obscure the true purpose of the study, and consistent with the cover story, participants were then asked to choose words that described their mood during each meal or snack (i.e. happy, angry, annoyed, sad/depressed, excited, content, anxious).

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 crisps[a]	25	136
Cadburys dairy milk chocolate buttons	60	321
Tesco stuffed crust cheese pizza	215	550
Brownies	50	192
Flapjacks[b]	50	224

UK to US translation.
[a] Chips.
[b] Oat bars.

3.1.3.3. Procedure. Testing took place between October 2019 and February 2020, and in the same room as in Study 1. Participants were invited to attend the Eating Behaviour Laboratory at the University of Birmingham between 12 and 2pm (to coincide with normal lunch hours), and were instructed to refrain from eating or drinking any calorie-containing drinks for at least 3 h before the start of their session. Participants arrived at the lab with their two friends.

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

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

Alcohol and non-alcoholic drinks were recorded but due to the high social intake of alcohol in this population we analysed the data with and without calories from alcohol. Between five and 14 days following the first lab session, participants returned to the lab to complete the following assessments: 1) demand characteristics were assessed by asking participants to write down what they thought the aims of the study were; 2) dietary restraint, uncontrolled eating, and emotional eating, were assessed using the TFEQ-18 (Karlsson et al., 2000) (described in Study 1); 3) friendship familiarity was assessed by asking participants to write down how long they have known each of the friends with whom they had participated (open ended question), and how well they felt they know these friends (1–10 scale anchored by 'Not very well' and 'Very well', respectively); and 4) other demographics, including age and ethnicity. Height and weight were then measured by the researcher to calculate BMI, and participants were fully debriefed as to the true aims of the study.

3.1.4. Data analysis

For the main variables of interest (calorie intakes in the lab and across days), outlying values were identified using Hoaglin and Iglewicz's (1987) outlier labelling rule. Because observations are non-independent (i.e. participants signed up to the study in groups of three), data were analysed using MLMs. In three separate analyses, Condition (Alone vs Social) was entered as a fixed-effects predictor of food consumed (kcal) during the lab session, of total intake (kcal) at the end of day 1 (lab intake + food diary intake for day 1) and of total intake at the end of day 4 (lab intake + food diary intake for days 1–4). Potential covariates were entered into a bivariate correlation matrix with the dependent variables. Variables that were significantly correlated with a dependent variable were included as covariates in the multi-level analyses. Statistical analyses were conducted using SPSS version 27.0 (IBM, 2020).

3.2. Results

3.2.1. Initial data checks

Initial inspection of the data revealed that calorie intake on day 1 (food diary data) was not normally distributed (skewness = 3.02, SE = 0.29; kurtosis = 15.06, SE = 0.58). Using Hoaglin and Iglewicz's (1987) outlier labelling rule, two participants were identified as outliers, having consumed over 1837 kcal on day 1 *after* the lab session (i.e. *not* including calories consumed within the lab or before lunch). Removing these participants corrected the distribution, and they were therefore excluded from subsequent analyses. No participants correctly guessed the aim of the study. Initial inspection of the data revealed that BMI correlated positively with the amount consumed during the lab session, r = 0.283, p = .021, total day 1 intake (i.e. lab intake + food diary intake for day 1), r = 0.322, p = .009, and total intake across all four days, r = 0.383, p = .002. BMI was therefore included as a covariate in the main analyses.

3.2.2. Participants

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

3.2.3. Effect of condition on food intake in the lab

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

3.2.4. Effect of condition on day 1 intake

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

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

3.2.5. Effect of condition on total four-day calorie intake

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

Table 4
Participant characteristics in Study 2.

	Alone condition (n = 34) Mean (SD)	Social condition (n = 33) Mean (SD)	Univariate test statistic
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[a]	7.2(1.6)	7.5(2.1)	F(1,64) = 0.25, p = .620

[a] 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?.

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

4. Discussion

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

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

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

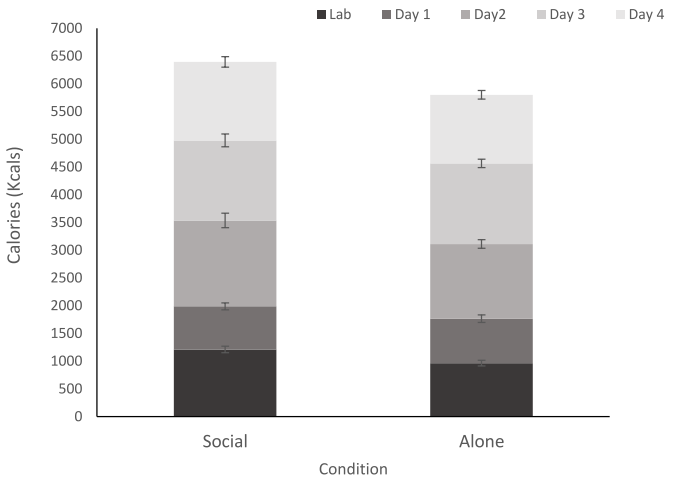

Fig. 2. Mean calories consumed as a function of condition and day. Error bars represent the standard error of the mean.

There are implications of the present results for healthy eating and nutritional interventions. Social eating might be used to increase the food intake of undernourished populations e.g. elderly people with reduced appetite. People who wish to avoid overeating, might wish to develop strategies that allow them to experience the benefits of social eating (Dunbar, 2017) while at the same time mitigating the effects of social context on excess calorie intake. One strategy may be to actively compensate for socially facilitated food intake by eating smaller meals before or after a social meal. Another strategy may be to advise people to plan their meal in advance of a social occasion. Indeed, in a recent study (Ruddock, Long, Brunstrom, Vartanian, & Higgs, 2021) we found that participants who served themselves *before* eating with a friend consumed significantly fewer calories than those who served themselves *during* the meal. Thus, pre-ordering food or serving oneself before the start of a meal, may help people to avoid unintentionally overeating during social meals.

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

A limitation of the present studies is that we did not measure energy expenditure and so we cannot rule out the possibility that participants compensated for additional calorie intake by expending more energy. In Study 1, participants recorded the amount of time that they had spent engaging in light, moderate, and vigorous exercise during the 24 h prior to each test day. Analysis of these data revealed no significant main effect of condition (Alone vs Social) on exercise duration, suggesting that participants did not compensate for socially facilitated food intake by engaging in more physical activity (see supplementary materials). However, future research could incorporate other more precise measures of energy expenditure (such as actigraphy). In addition, recruitment was restricted to women with a BMI within the normal weight range. It is therefore important for future research to establish the generalisability of our findings to other populations. To date there has been no systematic study of the moderating effects of weight status and/or sex/gender on social facilitation of eating. However data from self-report and observational studies indicate that people with overweight may show a weaker effect, perhaps because concerns about portraying a particular impression to others overrides social facilitation effects in these contexts (Salvy, de la Haye, Bowker, & Hermans, 2012).

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

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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.

Author contributions

SH, JB, LV & HR designed the research. Testing and data collection were performed by HR. HR performed the data analyses. SH, JB, LV & HR wrote the paper. All authors approved the final version of the manuscript for submission. SH had primary responsibility for final content.

Data sharing

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

Ethical statement

The study protocol was approved by the University of Birmingham's Research Ethics Committee and was conducted in line with ethical standards stated in the Declaration of Helsinki 1975.

Declaration of competing interest

Helen K. Ruddock "no conflicts of interest."
Jeff M. Brunstrom "no conflicts of interest."
Lenny R. Vartanian "no conflicts of interest."
Suzanne Higgs "no conflicts of interest."

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2022.106141.

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