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Eating rate and food intake are reduced when a food is presented in an ‘unusual’ meal context

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Abstract

Research has shown that 1) the slower a food is eaten the less food is consumed overall, and 2) context affects portion selection. This study aimed to explore whether eating rate and food intake are influenced by consuming food in ‘usual’ vs ‘unusual’ mealtime contexts. Furthermore, this study aimed to identify whether mealtime-specific appropriateness and previous consumption frequency corresponded with differences in eating rate and food intake between contexts. Seventy-eight participants were served either cheese and tomato pasta (a typical lunch food) or porridge with milk and honey (a typical breakfast food) *ad libitum* at both breakfast and lunch on separate days. Results showed that eating rate was slower (60.7 vs 71.2 g/min, $p < 0.001$) and less food was consumed (404.1 vs 543.2 g, $p < 0.001$) when participants ate cheese and tomato pasta at breakfast compared to at lunch. However, no significant differences in eating rate (54.6 vs 56.4 g/min, $p = 0.75$) or food intake (423.7 vs 437.7 g, $p = 0.88$) were found between mealtimes for porridge with milk and honey. Furthermore, differences in eating rate and food intake between contexts were not associated with differences in mealtime-specific appropriateness or previous consumption frequency. These results suggest that eating rate and *ad libitum* food intake are influenced by the congruency of the food-to-mealtime context; however, this effect is not associated with mealtime-specific appropriateness or previous consumption of the food. Further research should explore the implications of introducing foods at unusual mealtimes in relation to strategies for weight management.

Keywords: Eating rate, context, portion size, meal planning, energy intake, satiety.

1.0. Introduction

Pre-meal decisions regarding portion selection have been shown to greatly influence subsequent energy intake. Approximately 90% of meals are planned in advance, not only in terms of food type but also portion size, and most (~90%) are eaten in their entirety, known as ‘plate cleaning’ (Fay et al., 2011; Wilkinson et al., 2012). These pre-meal decisions are greatly influenced by learned expectations about a food’s sensory characteristics and its expected satiety (Brunstrom, 2014; Brunstrom & Rogers, 2009; McCrickerd & Forde, 2016). The more often a food is consumed, the more effortless pre-meal decisions become.

Research from our laboratory found that the influence of expected satiety (the perceived satiating ability of a food) on portion size selection was mediated by the context in which these decisions were made (McLeod, James, Brunstrom, & Witcomb, 2020). That is, when foods were presented at an unusual mealtime (e.g., pasta at breakfast time) smaller portions were selected to stave off hunger, and expected satiety did not play as influential a role in portion selection, compared to in more usual food-to-mealtime contexts (e.g., pasta at lunch time). This study raised two questions about food-to-mealtime associations. Firstly, which factors determine when a food is congruous or incongruous for a mealtime? We suggested that food-to-mealtime associations may form through frequent consumption of a food at a specific mealtime in the past (mealtime-specific previous consumption frequency) or through the perceived appropriateness of consuming a food at a given mealtime, learned implicitly through social cues rather than explicit food consumption. Secondly, it raised the question about whether food-to-mealtime associations affect actual energy intake and other variables that impact satiety and energy intake, such as eating rate.

Previous research exploring eating rate has been extensive, as presented in a meta-analysis by Robinson et al. (2014). Evidence shows that eating rate is a good predictor of food intake and body mass index (Hogenkamp & Schiöth, 2013; Leong, Madden, Gray, Waters, & Horwath, 2011; Llewellyn, Van Jaarsveld, Boniface, Carnell, & Wardle, 2008; Robinson et al., 2014). That is, individuals with slower eating rates tend to consume comparatively less food and have a lower BMI than those who tend to consume their meals faster. Explicit manipulations to reduce eating rate or increase chews per bite (e.g. by verbal or computerised cues; cutlery size or vibrotactile feedback; food texture; or via oral device) have been shown to successfully reduce energy intake while increasing satiation/satiety and decreasing the risk of later energy compensation (Andrade, Kresge, Teixeira, Baptista, & Melanson, 2012; Ferriday et al., 2016; Forde, van Kuijk, Thaler, de Graaf, & Martin, 2013; Hermans et al., 2017; James, Maher, Biddle, & Broom, 2016; Ryan et al., 2018; Scisco, Muth, Dong, & Hoover, 2011). Previous work has also shown how implicit and explicit cognitive factors can increase eating rate, such as eating while distracted (Blass et al., 2006; Bolhuis, Lakemond, de Wijk, Luning, & de Graaf, 2013), eating with others (de Castro, 1990, 1994, 1995), eating large servings (Almiron-Roig et al., 2015; Wilkinson et al., 2016) and eating highly palatable foods (Bobroff & Kissileff, 1986). Furthermore, Wilkinson et al. (2016) found that the perceived volume of a food portion (rather than the volume of food consumed in reality) can influence eating rate. That is, eating rate was faster when a portion of soup seemed small (300 ml) but the portion that participants actually consumed was larger (500 ml; achieved by covertly replenishing the soup bowl via a peristaltic pump) compared to when the portion of soup in the bowl seemed larger (500 ml) but where less soup was consumed in reality (300 ml). This finding infers that eating rate is not influenced

solely by a response to orosensory stimulation but by the perception of the portion of food available.

Therefore, it is possible that eating rate is also influenced by other cognitive factors, such as the food-to-mealtime context. Considering the eating rate literature and our previous findings, we hypothesised that in incongruous food-to-mealtime contexts eating rate would be slower and less food would be consumed compared to in the congruous food-to-mealtime contexts, without a difference in postprandial appetite between the food-to-mealtime contexts. This is important to investigate because confirming this hypothesis would present the manipulation of food-to-mealtime congruency as a potential novel weight management strategy. This strategy could involve the promotion of consuming liked and familiar foods at unusual mealtimes by weight management practitioners as method of reducing food intake, for example. Conversely, confirming this hypothesis would also indicate that larger portions are selected and eaten (at a quicker eating rate) in congruous food-to-mealtime contexts which may also present a positive clinical application. That is, if food products are marketed as being appropriate for a specific mealtime, this may lead to more food being consumed compared to if the food was not marketed meal-specifically. This strategy would be beneficial for vulnerable populations who need to increase energy intake, such as the elderly or infirm.

Therefore, this study aimed to explore 1) the impact of food-to-mealtime congruency on eating rate and food intake, and 2) the association between the difference in eating rate and food intake between food-to-mealtime contexts and the measures of perceived mealtime-specific appropriateness and previous consumption frequency for particular foods at particular mealtimes.

2.0. Methods

2.1. Overview

To investigate the aims of this study, participants were recruited for a mixed design; half consumed a typical breakfast food (porridge with milk and honey) and the other half a typical lunch food (cheese and tomato pasta) at two mealtimes (breakfast time and lunch time) *ad libitum* on separate days. The breakfast food consumed at breakfast time and the lunch food consumed at lunch time were considered congruous food-to-mealtime contexts. The breakfast food at lunch time and the lunch food at breakfast time were considered incongruous food-to-mealtime contexts. At each laboratory visit, eating rate, food intake and subjective measures of eating habits and food preference were recorded.

2.2. Participants

This study was open to males and females, aged 18 years and over. Participants were recruited via opportunity sampling from and around Loughborough University, UK. Vegans and vegetarians, those currently trying to lose weight, and those who did not habitually eat breakfast (at least 5 days a week, defined as “the first meal of the day, consumed within 2 h of waking”, Clayton & James, 2016) were excluded from the study. A screening questionnaire was also used to check that potential participants were not allergic to any of the foods to be consumed as part of the study, and to check that they liked (≥ 7 on a 10-point Likert scale, where 10 denoted the highest liking score, anchored with “Extremely”) the food to be consumed. These screening questions were asked for the test food (either cheese and tomato pasta or porridge with milk and honey, depending on group allocation) and four dummy foods; spaghetti carbonara, Bran Flakes with semi-skimmed milk, roasted vegetable and soft cheese sandwich, and toast with strawberry

jam. Five foods were included to ensure participants did not know which food was being used in the study.

Participants provided informed consent before starting the study and ethical approval was obtained from the Ethics Approvals (Human Participants) Sub-Committee (Loughborough University) (R18-P149).

2.3. Test foods

The procedure involved asking participants to consume either a breakfast-congruous food (porridge with milk and honey, referred to as ‘porridge’) or a lunch-congruous food (cheese and tomato pasta, referred to as ‘pasta’) at both breakfast and lunch times. These foods were selected as pilot research showed them to be commonly identifiable in the UK as regular breakfast and lunch meals, respectively. See Table 1 for manufacturer details, macronutrient, energy density and energy content of the test foods.

The participants were served the test food in an unoccupied room without distraction with white crockery (for pasta) or a translucent glass bowl (for porridge) and stainless-steel cutlery. Participants were offered a 250 ml glass of water with the test food – no further water was provided. The test food portion was the same for all participants in each group and was a ‘double portion’ (i.e., larger than an average standard portion of each food) to reduce the risk of ‘plate cleaning’ behaviour (pasta = 704-kcal portion, porridge = 699-kcal portion). Participants did not have any information about the size of the portion. The portion was presented to the participant with the knowledge that more was available. If participants consumed the initial portion to the point where a refill was required (i.e., when the computer program indicated that one fifth of the initial portion remained on the plate/bowl; see section 2.4.7 for further details), another double portion was provided.

Table 1.

Macronutrient, energy density and energy content of the cooked test foods (porridge with milk and honey, and cheese and tomato pasta) and ingredients per 100 g.

Test food	Carbohydrate (g)	Protein (g)	Fat (g)	Energy content (kcal)	Energy density (kcal/g)
Porridge with milk and honey	20.7	5.2	3.2	135.6	1.36
Oats*	58.0	12.0	8.7	374.0	3.7
Semi-skimmed milk*	4.8	3.6	1.8	50.0	0.5
Honey*	81.5	0.0	0.0	329.0	3.3
Cheese and tomato pasta	16.9	5.5	5.6	140.7	1.41
Fusilli pasta (cooked)*	31.6	5.2	0.86	176.4	1.8
Passata*	4.4	1.1	0.5	28.0	0.3
Cheddar cheese*	2.1	24.9	34.2	416.0	4.2
Olive oil*	0.0	0.0	100.0	900.0	9.0

* Brand is Tesco.

2.4. Measures

All measures (apart from Demographic information) were presented and collected using the Sussex Ingestion Pattern Monitor (SIPM) (University of Sussex, UK) computer program.

2.4.1. Demographic information. As part of the recruitment screening, participants completed an online questionnaire asking their age, sex and how much they liked the taste of five different foods (see section 2.1). Participants were also asked to complete the Three Factor Eating Questionnaire (TFEQ) (Stunkard & Messick, 1985). Height and body mass were measured at the beginning of the participant's final session with BMI calculated by the researcher.

2.4.2. Appetite. Pre- and post-prandial appetite was assessed using a composite score of hunger, fullness and general desire to eat (composite appetite score = (hunger + (100-fullness) + desire to eat) / 3) as used in previous studies (Monsivais, Perrigue, & Drewnowski, 2007; Perrigue, Drewnowski, Wang, & Neuhouser, 2015; Perrigue, Monsivais, & Drewnowski, 2009). Each measure was presented on a 100-mm visual-analogue rating scale (VAS). Participants were asked: “How hungry do you feel right now?” “How full do you feel right now?” and “How strong is your desire to eat right now?” The scales were anchored with “Not at all” (0 mm) and “Extremely” (100 mm).

2.4.3 Liking and desire to eat. Participants indicated their liking and desire to eat the test foods at each mealtime using a 100-mm VAS. The liking VAS was headed: “How much do you like the taste of the food in front of you in general?” and was anchored with “I hate it” (0 mm) and “I love it” (100 mm). Liking was measured before participants consumed the food. The desire to eat scale was headed: “How much do you want to eat this food right now?” and was asked after food had been presented, but before consumption. The VAS was anchored with “Not at all” (0 mm) and “Extremely” (100 mm).

2.4.4 Mealtime-specific previous consumption frequency. Participants indicated the frequency that they had previously consumed the test food at breakfast time or lunch time (depending on the trial). The question was headed: “At breakfast time/lunch time, I consume porridge with milk and honey/cheese and tomato pasta [n] times per...” with participants indicating their response per day, week, month or year (whichever was most appropriate).

2.4.5 Mealtime-specific appropriateness. Participants indicated how appropriate they believed the test food to be for each mealtime using a 100-mm VAS headed “How appropriate do

you think this food is to consume at this mealtime?”. The scale was anchored with “Not at all appropriate” (0 mm) and “Completely appropriate” (100 mm).

2.4.6 Postprandial meal enjoyment. Participants indicated how much they enjoyed consuming the test food at the end of the meal using a 100-mm VAS headed: “How much did you enjoy consuming this food at this mealtime?” The scale was anchored with: “Not at all” (0 mm) and “Extremely” (100 mm).

2.4.7. Eating rate and food intake. Eating rate was assessed through continuous measurements of plate/bowl mass (g) across the meal. A Sartorius Cubis MSU5201S series scale was connected via USB to a PC. Both the scale and the PC were placed on a table in front of the participant; however, the scale was concealed within a tailor-made table with a place mat positioned on top to hide the scale. During the meal, software written on the SIPM recorded the mass of the plate/bowl (g) at one second intervals. The reduction of scale mass throughout the eating session from food consumption was inverted to create cumulative intake data (a change in scale mass of <1 g was not considered a reduction in food from the plate/bowl). The computer program notified the researcher and participant via an alarm that one fifth of the initial portion remained on the plate/bowl. At this point, the researcher refilled the plate/bowl in a separate room in <60 s before presenting a full portion to the participant once more. The measurement of meal duration, recorded by the SIPM, did not stop for the refill interlude. Thus, after piloting, a standardised 10 s interval was decided upon to replace the duration of the refill interlude for all participants who reached the refill stage. The final time point (and the end of the eating session) was taken at the time point (s) of the last reduction of the scale mass >1 g. Overall meal duration was adjusted accordingly if the portion consumed included a refill interval.

Food intake was calculated by subtracting the mass of the test food at the end of the meal (g) from the mass of the test food at the beginning of the meal (g), minus the mass of the plate/bowl (g). Total mouthfuls per meal were calculated by coding the number of changes (>1 g) in cumulative food intake across the eating duration. Average mouthful size (g) was calculated by dividing food intake (g) by the number of mouthfuls per meal.

2.5. Procedure

Participants who expressed an interest in participating in the study were sent a link to an online information pack presented using the Online Survey platform (onlinesurveys.ac.uk). From here, participants read the information sheet and provided informed consent by ticking a box on the online form. Subsequently, participants completed the demographic questionnaire, TFEQ, baseline liking scale and indicated whether they had allergies or intolerances to the ingredients of the test foods. After completing the online questionnaire, eligible participants were contacted by the researcher to organise times for their breakfast and lunch trials.

Participants were asked to take part in two trials: breakfast (0800) and lunch (1200) on separate days (1-7 days apart) completed in a random, counter-balanced order. No familiarisation trial was conducted. To ensure hunger was controlled, participants were asked to refrain from eating for 12 h prior to the breakfast trial and for 3 h prior to the lunch trial, to avoid caffeine 12 h prior to each trial to avoid anorexigenic effects (Schubert et al., 2017), and to refrain from exercise for 24 h before experimental trials and for the day of the experimental trials. On each occasion, after entering the laboratory, participants were asked to rate their appetite (hunger, fullness and general desire to eat). On the participants' final session only, height and weight were then measured by the researcher. They were then presented with five sealed envelopes. The participants were told: "*A different food is contained within each envelope. Please select an*

240 *envelope. The food in the envelope you choose will be the meal you are allocated for your*
241 *breakfast/lunch today.”* In reality, each envelope had the test food enclosed. Once the food had
242 been selected, the researcher prepared the test food in a separate room. This covert strategy
243 occurred in all trials. Once the participant was presented with the food (but before the eating
244 session began) participants were asked to rate their liking, desire to eat, mealtime-specific
245 previous consumption frequency, and mealtime-specific appropriateness for the test food in front
246 of them. After completing these measures, the researcher said: “*You have 30 minutes or less to*
247 *consume as much or as little food as you would like, knowing that you will not be able to eat for*
248 *3 hours after you’ve finished your meal. Please don’t move the plate/bowl or place your cutlery*
249 *on it. There is more food available than the portion you see in front of you but you don’t have to*
250 *worry about letting me know if you would like more as an alarm will sound on the computer once*
251 *you have consumed a certain amount. At that point, I will enter and replenish your portion for*
252 *you. Once you have finished, please press the ‘meal finished’ button on the computer screen and*
253 *I will be alerted to come in.*” The instructions were presented on the computer screen during the
254 eating session as a reminder. The eating session then began without distraction, with eating rate
255 recorded covertly (detailed in section 2.4.7). After participants had consumed the meal (with or
256 without refills) to their satisfaction, the researcher asked the participant to rate their appetite and
257 postprandial meal enjoyment. After the final trial, the researcher asked if the participant knew the
258 intention of the research before debriefing them on the protocol. No participants guessed that
259 eating rate was being measured or that there was the intention to create incongruous food-to-
260 mealtime contexts. However, two participants guessed that food intake was being recorded.

2.6. Data analysis

All data were analysed using SPSS V24 software (SPSS Inc.). Significance was accepted at $p < 0.05$. All data are presented as average scores with standard deviation (SD) unless otherwise stated. The Greenhouse-Geisser correction was applied to adjust the degrees of freedom where sphericity had been violated. Effect sizes were presented as r -values, as data were parametric and non-parametric, which were calculated from F -, Z - and t -values using equations by Rosenthal (1994); benchmarks were demarcated as small if $r = |0.1|$, medium if $r = |0.3|$ and large if $r = |0.5|$ (Cohen, 1992).

Between-group differences in participant characteristics were assessed via one-way ANOVAs. A MANOVA was conducted to analyse the main effect and interaction terms for eating rate, food intake, eating duration, total mouthfuls and average mouthful size. Univariate analysis of each variable further investigated the significant MANOVA interaction. Two (mealtimes) by two (food groups) ANOVAs were conducted to analyse main effect and interaction terms for pre- and post-meal composite appetite scores, liking, desire to eat, mealtime-specific appropriateness and previous consumption frequency scores, and postprandial meal enjoyment scores. Significant interactions were explored by conducting two planned *post hoc* paired-samples t -tests to explore the difference in scores between breakfast time and lunch time for pasta and porridge, respectively. As multiple comparisons were conducted, the increased likelihood of Type 1 error was addressed by applying a Bonferroni correction at each level of analysis. All p -values are presented with the Bonferroni correction applied.

Eating rate was divided into quartiles in order to investigate whether changes in eating rate occurred during the course of each participant's meal duration or whether eating rate was consistently higher, lower or the same throughout the meal, in different food-to-mealtime

contexts (Almiron-Roig et al., 2015; Westerterp-Plantenga, 2000). Four eating rate per quartile scores were calculated for each of the four food-to-mealtime contexts. Subsequently, two separate 2 (mealtime) by 4 (quartile) ANOVAs were conducted (one for pasta, one for porridge) to assess the difference in eating rate quartiles between mealtimes.

Correlation analysis was used to explore the association between eating rate, food intake, mealtime-specific previous consumption frequency, mealtime-specific appropriateness, desire to eat, and postprandial meal enjoyment. This was conducted to analyse correlations within 1) congruous contexts, 2) incongruous contexts, and 3) for change scores, i.e., differences (per participant) in eating rate and food intake (respectively) between congruous and incongruous contexts. Change scores were calculated as the square of the difference (incongruous context score minus congruous context score, squared $[(INC-C)^2]$). This analysis combined the data from both the pasta and porridge groups. Shapiro-Wilk tests indicated that data for several variables were not normally distributed ($W_{(78)} = [0.41, 0.98]$, $p = [< 0.001, 0.19]$); thus a non-parametric Kendall's tau assay was used to explore these correspondences.

3.0. Results

3.1. Participant characteristics

Each group ($n = 39$) consisted of 18 males and 21 females with an overall mean age of 26.0 ± 11.4 years. One additional participant in the cheese and tomato pasta group was excluded prior to the analysis as it was clear that they did not like the pasta. Mean participant BMI and TFEQ scores for restraint, disinhibition and hunger were within the normal range (Stunkard & Messick, 1985; see Table 2 for further demographic information).

Table 2.

Participant characteristics ($n = 78$) for Group 1 ($n = 39$; pasta) and Group 2 ($n = 39$; porridge) and the results of the between-groups ANOVAs.

Participant characteristic	Mean scores ($\pm$ SD)		F	p
	Group 1 (pasta)	Group 2 (porridge)		
Age (yr)	24.8 (9.0)	27.1 (13.7)	0.77	0.38
Height (cm)	172.2 (9.5)	172.3 (8.1)	0.01	0.93
Weight (kg)	69.7 (12.2)	69.4 (11.0)	0.02	0.89
BMI (kg/m^2)	23.5 (3.6)	23.3 (2.7)	0.10	0.75
TFEQ-Restraint	7.8 (5.3)	7.8 (4.0)	0.002	0.96
TFEQ-Disinhibition	6.9 (3.6)	6.0 (3.3)	1.26	0.27
TFEQ-Hunger	5.9 (3.2)	6.1 (3.3)	0.06	0.81

Note: all $df_{\text{effect}} = 1$, all $df_{\text{error}} = 77$.

3.2. Pre-meal appetite and liking

For pre-meal appetite, there was no significant effect of food group ($F_{(1,76)} < 0.001$, $p = 0.99$, $r < |0.01|$), or mealtime ($F_{(1,76)} = 0.777$, $p = 0.38$, $r = |0.10|$) and there was a non-significant mealtime-by-food group interaction ($F_{(1,76)} = 0.191$, $p = 0.66$, $r = |0.05|$). This indicated that average pre-meal composite appetite scores did not differ significantly between mealtimes for the pasta group (breakfast time = 72.9 ± 14.3 mm; lunch time = 71.9 ± 17.8 mm), the porridge group (breakfast time = 73.9 ± 19.4 mm; lunch time = 70.8 ± 17.3 mm) or between groups.

For subjective liking scores, there were no significant effects of mealtime ($F_{(1,76)} = 0.24$, $p = 0.63$, $r = |0.06|$) or food group ($F_{(1,76)} = 2.00$, $p = 0.16$, $r = |0.16|$), and no significant mealtime-by-food-group interaction ($F_{(1,76)} = 0.14$, $p = 0.71$, $r = |0.04|$). These results indicated that participants' subjective liking scores did not differ significantly between mealtimes or food groups (pasta group: breakfast time = 81.8 ± 14.3 mm, lunch time = 81.6 ± 14.0 mm; porridge group: breakfast time = 77.9 ± 17.0 mm, lunch time = 76.6 ± 16.1 mm).

3.3. Eating rate, food intake, eating duration, total and average mouthfuls per meal

The MANOVA on the combined variables (eating rate, food intake, eating duration, total and average mouthfuls per meal) revealed a significant mealtime-by-food-group interaction ($F_{(5,72)} = 4.07, p = 0.003$, Pillai's trace = 0.22, $r = |0.47|$), a significant effect of mealtime ($F_{(5,72)} = 6.38, p < 0.005$, Pillai's trace = 0.31, $r = |0.55|$) and a non-significant effect of food group ($F_{(5,72)} = 1.49, p = 0.20$, Pillai's trace = 0.09, $r = |0.31|$). Univariate analysis explored the significant interaction term further (see Table 3 for full univariate analysis results).

For eating rate, there was a significant effect of mealtime ($p < 0.001$) and a mealtime-by-food-group interaction ($p = 0.01$) but no effect of food group ($p = 0.09$). *Post hoc* analysis indicated that eating rate increased significantly from breakfast time to lunch time for pasta ($t_{(38)} = -4.23, p < 0.001, r = |0.57|$) but did not increase significantly for porridge ($t_{(38)} = -0.90, p = 0.75, r = |0.14|$) (see Figure 1).

Figure 1. Mean ($\pm$ SEM) eating rate (g/min) for cheese and tomato pasta and porridge with milk and honey at breakfast time and lunch time.

* Eating rate was higher at lunch time compared to breakfast time ($p < 0.001$).

** Eating rate increased significantly from breakfast time to lunch time for the pasta group ($p < 0.001$) but did not differ significantly for the porridge group ($p = 0.75$).

Furthermore, when eating rate was analysed per quartile for pasta and porridge, respectively, the non-significant interactions indicated that changes in eating rate per quartile throughout the meal were not significantly different between mealtimes for either food (pasta: $F_{(2.51,95.38)} = 0.21, p = 0.86, r = |0.08|$; porridge: $F_{(1.82,69.12)} = 0.08, p = 0.91, r = |0.04|$). See Figure 2 for further details.

Figure 2. Mean ($\pm$ SEM) eating rate (g/min) per quartile for cheese and tomato pasta and porridge with milk and honey at breakfast time and lunch time.

Letters a-d that are different indicate a significant difference between pasta mealtimes and quartiles.

Letters e-g that are different indicate a significant difference between porridge mealtimes and quartiles.

For food intake, there was a significant effect of mealtime ($p < 0.001$) and a significant mealtime-by-food-group interaction ($p < 0.001$), but no significant effect of food group ($p = 0.25$). *Post hoc* analysis indicated that food intake increased significantly from breakfast to lunch for pasta ($t_{(38)} = -6.36, p < 0.001, r = |0.72|$) but did not increase significantly for porridge ($t_{(38)} = -0.78, p = 0.88, r = |0.13|$) (see Figure 3).

Figure 3. Mean ($\pm$ SEM) food intake (g) for cheese and tomato pasta and porridge with milk and honey at breakfast time and lunch time.

* Food intake was higher at lunch time compared to breakfast time ($p < 0.001$).

** Food intake increased significantly from breakfast time to lunch time for the pasta group ($p < 0.001$) but did not differ significantly for the porridge group ($p = 0.88$).

For eating duration, there were no significant effects of mealtime or food group, nor a significant interaction ($p \geq 0.08$), indicating no significant difference in eating duration between mealtimes for the pasta group (breakfast time = 7.3 ± 2.9 min; lunch time = 8.2 ± 2.4 min) or porridge group (breakfast time = 8.7 ± 4.1 min; lunch time = 8.8 ± 4.3 min).

For total mouthfuls per meal, a significant mealtime-by-food-group interaction ($p = 0.02$) with *post hoc* analysis indicated that more mouthfuls were taken by the pasta group at lunch time (45.2 ± 18.9) compared to breakfast time (36.6 ± 14.9 ; $t_{(38)} = -4.91$, $p < 0.001$, $r = |0.62|$). There was no significant change in total mouthfuls per meal for the porridge group at lunch time (38.3 ± 13.1) compared to breakfast time (35.7 ± 13.0 ; $t_{(38)} = -1.51$, $p = 0.28$, $r = |0.24|$).

The significant mealtime effect for the average size of mouthfuls per meal ($p = 0.048$) indicated that slightly larger mouthfuls were taken at lunch time (13.0 ± 4.7 g) compared to breakfast time (12.0 ± 4.5 g). The non-significant interaction ($p = 0.097$) indicated that there was no difference between pasta or porridge groups in the inter-mealtime differences.

Table 3.

Main effects and interactions from the univariate analyses for eating rate, food intake, average total mouthfuls, mouthful size and eating duration, and from the ANOVAs for postprandial appetite, mealtime-specific appropriateness, mealtime-specific consumption frequency, desire to eat and meal enjoyment.

Variable	Factor	<i>F</i>	<i>p</i>	<i>Effect size (r)</i>
Eating rate	Mealtime	13.63	<0.001	0.39
	Food group	3.04	0.09	0.19
	Mealtime x food group	6.67	0.01	0.28
Food intake	Mealtime	29.34	<0.001	0.53
	Food group	1.33	0.25	0.13
	Mealtime x food group	19.60	<0.001	0.45

Variable	Factor	<i>F</i>	<i>p</i>	<i>Effect size (r)</i>
Average total mouthfuls	Mealtime	20.82	<0.001	0.46
	Food group	1.57	0.22	0.14
	Mealtime x food group	6.01	0.02	0.27
Average mouthful size	Mealtime	4.03	0.048	0.22
	Food group	0.001	0.95	0.01
	Mealtime x food group	0.003	0.97	0.01
Average eating duration	Mealtime	3.13	0.08	0.20
	Food group	2.01	0.16	0.16
	Mealtime x food group	2.47	0.12	0.18
Postprandial appetite	Mealtime	2.53	0.12	0.18
	Food group	0.20	0.66	0.05
	Mealtime x food group	8.80	0.004	0.48
Appropriateness	Mealtime	<0.001	0.99	<0.001
	Food group	2.87	0.09	0.19
	Mealtime x food group	300.94	<0.001	0.89
Consumption frequency	Mealtime	4.23	0.043	0.23
	Food group	4.55	0.036	0.24
	Mealtime x food group	58.03	<0.001	0.66
Desire to eat	Mealtime	3.02	0.09	0.20
	Food group	2.87	0.10	0.19
	Mealtime x food group	64.63	<0.001	0.68
Meal enjoyment	Mealtime	0.25	0.62	0.06
	Food group	1.18	0.28	0.12
	Mealtime x food group	66.61	<0.001	0.68

Note: All variables are 'per meal'. All $df_{effect} = 1$, all $df_{error} = 76$.

3.4. Postprandial appetite, mealtime-specific appropriateness, mealtime-specific previous consumption frequency, desire to eat and postprandial meal enjoyment

See Table 3 for full ANOVA results. For the postprandial appetite scores, there was no significant effect of mealtime or food group ($p \geq 0.12$). However, the significant mealtime-by-food-group interaction ($p = 0.004$) and *post hoc* analysis indicated that participants were slightly less full after they had eaten pasta at breakfast time (13.9 ± 11.4 mm) compared to at lunch time

(9.0 ± 8.9 mm; mean difference between mealtimes = 4.9 mm; $t_{(38)} = 3.40$, $p = 0.004$, $r = |0.48|$).

There was no significant difference between postprandial appetite scores for porridge at breakfast time (11.8 ± 11.1 mm) and lunch time (13.3 ± 14.3 mm; mean difference between mealtimes = 1.5 mm; $t_{(38)} = -0.93$, $p = 0.72$, $r = |0.15|$).

There were no significant main effects of mealtime or food group for mealtime-specific appropriateness ($p \geq 0.09$). However, the significant mealtime-by-food-group interaction ($p < 0.001$) with *post hoc* analysis indicated that pasta was rated as very appropriate for lunch time (90.8 ± 12.6 mm) and not appropriate for breakfast time (28.4 ± 26.0 mm; $t_{(38)} = -12.26$, $p < 0.001$, $r = |0.89|$), whereas porridge was rated as very appropriate for breakfast time (96.3 ± 10.1 mm) and not appropriate for lunch time (34.0 ± 30.0 mm; $t_{(38)} = 12.27$, $p < 0.001$, $r = |0.89|$).

A similar interaction was observed for the meal-specific consumption frequency data ($p < 0.001$). *Post hoc* analysis indicated that pasta was consumed more frequently at lunch time (63.5 ± 55.5 times per year) than at breakfast time (2.8 ± 11.1 times per year; $t_{(38)} = -7.27$, $p < 0.001$, $r = |0.76|$), and that porridge was consumed more frequently at breakfast time (110.4 ± 127.3 times per year) than at lunch time (4.8 ± 10.0 times per year; $t_{(38)} = 5.24$, $p < 0.001$, $r = |0.65|$).

A similar pattern was observed for the desire to eat data. There were no significant main effects of mealtime or food group ($p \geq 0.09$). However, there was a significant mealtime-by-food-group interaction ($p < 0.001$). *Post hoc* analysis indicated that pasta was desired more at lunch time (80.4 ± 16.3 mm) than at breakfast time (63.5 ± 21.6 mm; $t_{(38)} = -4.23$, $p < 0.001$, $r = |0.57|$), and porridge was desired more at breakfast time (78.4 ± 19.8 mm) than at lunch time (52.3 ± 24.7 mm; $t_{(38)} = 7.33$, $p < 0.001$, $r = |0.77|$).

Finally, for postprandial meal enjoyment, there was no significant effect of mealtime or food group ($p \geq 0.28$) but, there was a significant interaction ($p < 0.001$). *Post hoc* analysis

indicated that postprandial meal enjoyment scores were higher (i.e., the meal was more enjoyable) in the congruous contexts compared to the incongruous contexts (pasta: $t_{(38)} = -5.44$, $p < 0.001$, $r = |0.66|$, breakfast time = 58.2 ± 22.5 mm, lunch time = 83.1 ± 19.6 mm; porridge: $t_{(38)} = 6.34$, $p < 0.001$, $r = |0.72|$; breakfast time = 77.4 ± 20.8 mm, lunch time = 55.4 ± 23.1 mm).

3.5. Correlations

Table 4 provides full correlation data and statistics. Eating rate and food intake were significantly and positively correlated in congruous contexts ($r = 0.52$, $p < 0.001$), in incongruous contexts ($r = 0.39$, $p < 0.001$) and when analysing the difference in eating rate and food intake, respectively, between congruous and incongruous contexts ($r = 0.25$, $p = 0.001$). That is, faster food consumption was associated with more food being consumed (and *vice versa*), and the larger the change in eating rate between the congruous and incongruous context the larger the change in food intake (and *vice versa*).

Differences in eating rate and food intake between contexts (change scores) were not significantly associated with differences in mealtime-specific appropriateness ($p \geq 0.84$), mealtime-specific frequency ($p \geq 0.10$), desire to eat ($p \geq 0.08$), postprandial meal enjoyment ($p \geq 0.35$) or general consumption frequency ($p \geq 0.10$). In incongruous contexts, eating rate was only significantly associated with meal enjoyment ($r = 0.21$, $p = 0.007$). In congruous contexts, eating rate was only significantly associated with desire to eat ($r = 0.19$, $p = 0.01$). In congruous and incongruous contexts, food intake was additionally significantly associated with postprandial meal enjoyment (congruous contexts: $r = 0.20$, $p = 0.01$; incongruous contexts: $r = 0.17$, $p = 0.03$) as well as with desire to eat (congruous contexts: $r = 0.23$, $p = 0.003$; incongruous contexts: $r = 0.18$, $p = 0.02$).

Mealtime-specific appropriateness was associated with desire to eat and meal enjoyment, in both contexts, and for change scores ($p \leq 0.01$). Mealtime-specific appropriateness was associated with mealtime-specific previous consumption frequency only in incongruous contexts ($r = 0.32, p < 0.001$).

Table 4.

Associations between eating rate, food intake, mealtime-specific previous consumption frequency, mealtime-specific appropriateness, desire to eat, postprandial meal enjoyment and general consumption frequency.

		Food intake			MSPCF			Appro.			DTE			PP Meal Enjoyment			GCF		
		Con	Incon	Ch	Con	Incon	Ch	Con	Incon	Ch	Con	Incon	Ch	Con	Incon	Ch	Con	Incon	Ch
Eating rate	Con	$r = 0.52$ $p < 0.001$			$r < 0.001$ $p > 0.99$			$r = 0.02$ $p = 0.78$			$r = 0.19$ $p = 0.01$			$r = 0.15$ $p = 0.06$			$r = 0.002$ $p = 0.98$		
	Incon		$r = 0.39$ $p < 0.001$			$r = -0.08$ $p = 0.38$			$r = -0.01$ $p = 0.95$			$r = 0.11$ $p = 0.16$			$r = 0.21$ $p = 0.007$			$r = 0.07$ $p = 0.38$	
	Ch			$r = 0.25$ $p = 0.001$			$r = 0.13$ $p = 0.10$			$r = 0.012$ $p = 0.88$			$r = 0.14$ $p = 0.08$			$r = 0.05$ $p = 0.55$			$r = 0.13$ $p = 0.10$
Food intake	Con				$r = -0.06$ $p = 0.44$			$r = -0.02$ $p = 0.79$			$r = 0.23$ $p = 0.003$			$r = 0.20$ $p = 0.01$			$r = -0.02$ $p = 0.77$		
	Incon					$r = 0.03$ $p = 0.75$			$r = 0.04$ $p = 0.64$			$r = 0.18$ $p = 0.02$			$r = 0.17$ $p = 0.03$			$r = 0.02$ $p = 0.76$	
	Ch						$r = -0.11$ $p = 0.17$			$r = -0.02$ $p = 0.84$			$r = -0.03$ $p = 0.71$			$r = 0.07$ $p = 0.35$			$r = -0.06$ $p = 0.46$
MSPCF	Con							$r = -0.02$ $p = 0.83$			$r = 0.06$ $p = 0.44$			$r = 0.004$ $p = 0.96$			$r = 0.75$ $p < 0.001$		
	Incon								$r = 0.42$ $p < 0.001$			$r = 0.10$ $p = 0.25$			$r = 0.20$ $p = 0.02$			$r = 0.10$ $p = 0.27$	
	Ch									$r = -0.09$ $p = 0.25$			$r = 0.06$ $p = 0.42$			$r = 0.004$ $p = 0.96$			$r = 0.73$ $p < 0.001$
Appro.	Con										$r = 0.28$ $p = 0.002$			$r = 0.22$ $p = 0.01$			$r = -0.03$ $p = 0.76$		
	Incon											$r = 0.20$ $p = 0.01$			$r = 0.32$ $p < 0.001$			$r = 0.06$ $p = 0.45$	
	Ch												$r = 0.23$ $p = 0.004$			$r = 0.23$ $p = 0.003$			$r = -0.07$ $p = 0.36$
DTE	Con													$r = 0.49$ $p < 0.001$			$r = 0.08$ $p = 0.32$		
	Incon														$r = 0.44$ $p < 0.001$			$r = 0.06$ $p = 0.48$	
	Ch															$r = 0.31$ $p < 0.001$			$r = 0.07$ $p = 0.38$
PP Meal Enjoyment	Con																$r = 0.02$ $p = 0.80$		
	Incon																	$r = 0.006$ $p = 0.94$	
	Ch																		$r = 0.002$ $p = 0.98$

Notes: MSPCF = Mealtime-specific previous consumption frequency. Appro. = Mealtime-specific appropriateness. DTE = Desire to eat. PP Meal Enjoyment = Postprandial meal enjoyment. GCF = General consumption frequency. Con = Congruous contexts. Incon = Incongruous contexts. Ch = change (square of the difference) between congruous and incongruous contexts.

4.0. Discussion

This study explored whether eating rate and food intake are reduced when food is consumed at incongruous (vs congruous) mealtimes. Our main finding was that eating rate was slower and less food was consumed in only one of the incongruous contexts (pasta at breakfast time). Comparatively, eating rate and food intake were similar between contexts for porridge. For the pasta group, average total mouthfuls increased from breakfast time to lunch time, with no significant change or difference in eating duration or average mouthful size for either food group. This suggests that the increase in eating rate related to an increase in mouthfuls per minute rather than mouthful size.

Our results revealed that eating rate and food intake were correlated, corroborating previous findings (Robinson et al., 2014). Therefore, it is likely that changes in eating rate and/or food intake are driving the response from the other and referring to previous studies in this area allows us to further dissect this interaction. A study from our laboratory investigating pre-meal decisions revealed that both smaller ideal portions, and portions selected to stave off hunger were chosen when foods were presented in incongruous contexts (e.g., lunch foods at breakfast time) compared to congruous contexts (e.g., lunch foods at lunch time) (McLeod et al., 2020). Research has also shown that smaller portions engender slower eating rates (Almiron-Roig et al., 2015; Wilkinson et al., 2016). This suggests that participants in our current study may have made pre-meal decisions (with or without conscious thought) to consume less food in an unusual context compared to in a usual context and that these pre-meal decisions to consume less food may have led to a slower eating rate. That said, another possibility is that food may have been consumed slower in unusual contexts as more conscious thoughts about the food's characteristics (e.g., flavour, palatability, fillingness) and about when to stop eating are considered during the

meal. Conversely, in usual contexts, these food-related thoughts and decisions may be more effortless because the process of food selection and consumption has become somewhat more practiced, leading to a quicker eating rate. However, the eating rate data per quartile in the current study does not support this latter hypothesis as eating rate decreased sequentially and similarly between quartiles for both porridge and pasta in both congruous and incongruous contexts. If thoughts and decisions about the food were more considered in unusual contexts, we would perhaps expect to see a slower eating rate in the first quartile as participants become accustomed to consuming the food in a novel context. As this was not the case, we expect that pre-meal decisions to consume a smaller portion led to a slower eating rate.

These results build on previous findings to suggest that there may be clinical application to consuming a food at unusual mealtimes for healthy weight management. That is, in unusual food-to-mealtime contexts, smaller portions may be selected as an ideal portion, expectations of satiety may be satisfied with less food (McLeod et al., 2020), and food may be eaten slower, with less food consumed. However, for the manipulation of food-to-mealtime congruency to be a beneficial strategy for reducing food intake, postprandial hunger should be abated to the same extent in both usual and unusual contexts. Although our findings showed that postprandial appetite was greater when participants consumed pasta at breakfast time compared to at lunch time, the difference between the scores was small. That is, when also considering the postprandial appetite scores for porridge with milk and honey (which had no significant difference between contexts), the range of average postprandial appetite scores was from 9.0 mm to 13.9 mm, a difference of < 5 mm on a 100-mm VAS. Notwithstanding this small but significant difference, future work should explore whether energy compensation occurs later in the day after consuming a food at an incongruous mealtime. Research should also investigate

how long this strategy might be effective before an incongruous food-to-mealtime association is normalised. These considerations are important to understand as introducing foods at unusual mealtimes may increase dietary variety which has been shown to compromise control of food intake (Hardman, Ferriday, Kyle, Rogers, & Brunstrom, 2015). Thus, until further research is undertaken, increasing the variety of food options that are appropriate for an individual to consume at a particular mealtime should be facilitated with caution.

These results may also have positive implications for vulnerable populations (such as the elderly or infirm) who need to increase food intake. That is, in congruous food-to-mealtime contexts, larger portions (with lower expected satiety) may be selected, food may be eaten quicker and more food may be consumed. Therefore, future research should explicitly investigate whether foods marketed as mealtime-specific are more likely to be selected for consumption and are associated with higher food intake. If research confirmed this hypothesis, and this strategy was implemented with food products of nutritionally-beneficial composition (e.g., high in energy density) this approach would add to implicit nudge strategies designed to improve the nutrition of vulnerable populations (Lakerveld et al., 2018; Thaler & Sunstein, 2009).

We aimed to confirm that our manipulation of food-to-mealtime congruency was achieved (i.e., porridge was considered a breakfast food only, and pasta was considered a lunch food only) by observing high ratings of appropriateness, mealtime-specific previous consumption frequency, desire to eat and post-meal enjoyment in congruous contexts, and comparatively lower ratings in incongruous contexts. To this extent, our manipulation was successful as all measures differed between contexts, as expected. However, notwithstanding these results, the eating rate and food intake patterns between congruous and incongruous contexts differed for the pasta and porridge groups. This pattern of results reflects the findings

from our previous work (McLeod et al., 2020). With this in mind, the exploratory analysis in the current study aimed to reveal the correspondence between eating rate, food intake and the subjective measures in order to better understand the mechanism underlying the influence of food-to-mealtime congruency. Specifically, our previous work implicated mealtime-specific previous consumption frequency and mealtime-specific appropriateness as potential influential factors. However, our analysis found no consistent association between eating rate, food intake and the subjective measures in this study. Therefore, other factors and mechanisms may help to explain these changes and we provide three speculative suggestions. Firstly, a measure of disgust might better capture the experience of eating foods in different contexts, e.g., eating pasta at breakfast time may be more disgusting to consumers than eating porridge at lunch time. Secondly, differences in portion selection, eating rate and consumption between contexts might be flavour-related, e.g., different for sweet vs savoury foods. Thirdly, it is possible that the difference in the homogeneity of our food choices played a role in our results; that is, porridge with milk and honey is more homogenous in texture than cheese and tomato pasta. Chewing might be a more arduous task in the morning and pasta requires slightly more chewing than porridge. A thick, savoury soup, for example, might be used as a comparison to porridge in subsequent work.

This study had a few limitations to highlight. Firstly, two participants stated at the debrief that they were aware that food intake was being measured. This may have changed the amount of food they consumed. Similarly, the use of an alarm to indicate when participants had consumed four fifths of their initial portion may have alerted participants to the fact that their eating was being observed. This may have affected their willingness to eat more of the food (particularly when the food was presented at an unusual mealtime). That said, previous work showed that

participant awareness of food intake being measured did not influence food intake with a main pasta dish (whereas it did influence intake for snack foods) (Thomas, Dourish, & Higgs, 2015). Furthermore, only two of 78 participants reported this awareness presenting a low risk of a confounded dataset. Secondly, the measures of mealtime-specific previous consumption frequency and appropriateness were assessed before participants consumed their food. This pre-meal assessment may have primed participants to more-consciously consider the food-to-mealtime association which may have impacted eating rate and food intake. Future work should assess mealtime-specific previous consumption frequency and appropriateness after the eating session.

In conclusion, this study found that eating rate and food intake are reduced when a food is consumed at an unusual mealtime. Previous research on the influence of the food-to-mealtime context on pre-meal portion selections leads us to believe that pre-meal decisions to consume less food, when it is presented in an unusual context, subsequently influences eating rate and food intake. This finding has a potential clinical application as a weight management strategy to decrease food intake. However, future research should explore the longer-term effects of the acute reduction in food intake in incongruous contexts (such as whether energy compensation occurs at a later meal) and how long this strategy may be beneficial. This finding also has a potential clinical application to increase food intake as, conversely, larger portions are consumed when foods are mealtime-congruous. Therefore, future work should investigate whether marketing foods as mealtime-specific could be a successful implicit nudge strategy to increase food intake and improve the nutrition of vulnerable populations.

Conflict of interest

The authors declare no conflict of interest.

Author contributions

Conceptualisation, writing (reviewing and editing) and methodology: C.J.M., L.J.J., and G.L.W.; investigation, formal analysis, computer programming and writing (original draft): C.J.M..

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