**Out of the lab and into the wild: the influence of portion size on food intake in laboratory vs. real-world settings.**

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**Abstract**

External influences on eating behaviour, such as portion size, have been reliably shown to influence food intake in the laboratory. However, little research has examined whether laboratory settings under or overestimate the effect that external influences have on food intake compared to when studied in the real-world. In Study 1, 60 participants (mean age = 32 years) were randomized to consume a large (200 g) or small (100 g) portion of popcorn under controlled laboratory conditions and during a separate session in their home. Results showed that the effect of portion size on food intake was larger at home (*d* = 0.97) than in the laboratory (*d* = 0.56). Furthermore, participants reported feeling more relaxed eating at home compared to the laboratory. In Study 2, we examined whether comparable results were observed in a semi-naturalistic laboratory designed to resemble a home setting. Fifty-nine participants (mean age = 28 years) completed the same procedure as Study 1 in a standard and a semi-naturalistic laboratory setting. Although participants reported having higher levels of private self-awareness in the standard laboratory, the effect that portion size had on food intake did not differ between the standard laboratory (*d* = 0.50) and the semi-naturalistic laboratory (*d* = 0.49). The impact that external influences on eating, such as portion size, have on food intake in the real-world may be underestimated when studied under laboratory conditions.

**Key words:** Portion size; eating behaviour; ecological validity; real-world; laboratory; food intake

**List of abbreviations:** BMI (Body Mass Index), TFEQ (Three Factor Eating Questionnaire), SSAS (Situational Self-Awareness Scale), VAS (Visual Analogue Scale).

1. **Introduction**

External factors, such as portion size, have been shown to causally influence food intake (Hollands et al., 2015; Zlatevska, Dubelaar, & Holden, 2014). To date, studies have tended to examine the impact of portion size on eating behaviour in laboratory settings (Haynes et al., 2020; Reale et al., 2019; Rolls et al., 2002; Sheen, Hardman, & Robinson, 2018; Zlatevska et al., 2014). A benefit of using laboratory measures is that they allow for precise measurement of food intake under controlled conditions (Blundell et al., 2010). In line with this, there is evidence that measures of food intake used in the laboratory have reasonable internal validity (Gregersen et al., 2008; Martin et al., 2005; Robinson et al., 2017). However, a critical issue when considering the validity of laboratory methods is the extent to which findings from the laboratory generalise to eating behaviour in the real-world.

The concern that eating behaviour in the laboratory is artificial and therefore unlikely to accurately reflect real-world eating is not a new idea (de Castro, 2000; Meiselman, 1992). However, the extent to which eating behaviours measured in the laboratory, specifically food intake, align with those taken in the real-world has received limited empirical attention. Of the research which has been conducted, studies have demonstrated that aspects of eating behaviour can change when measured in a naturalistic environment (compared to the laboratory), such as food acceptance (García-Segovia et al., 2015), liking of a food (Holthuysen, Vrijhof, de Wijk, & Kremer, 2017; King, Weber, Meiselman, & Lv, 2004; Meiselman, Johnson, Reeve, & Crouch, 2000) and eating rate (Petty, Melanson, & Green, 2013). Comparisons of environmental influences on food intake between naturalistic and laboratory settings have also received some, but limited attention. For example, Weber, King and Meiselman (2004) found that pizza consumption was greater in a restaurant-like environment compared with a standard eating environment when eating in the presence of others. Kim and Kissileff (1996) compared food intake after a glucose preload when consumed alone in a laboratory, or with a partner in a cafeteria, but found no difference in food intake between environments. Importantly, neither of these studies measured the effect of environment in isolation, but did so in the presence of other confounding factors such as social facilitation.

 One aspect of laboratory-based measurements of eating behaviour that is likely to differ to the real-world is that participants may be more aware that their behaviour is being measured. This is important because eating behaviour is known to be influenced by self-presentation motives (Pliner & Chaiken, 1990; Robinson, Blissett, & Higgs, 2013). For example, restriction of food intake has been shown to occur when concerns relating to impression management (changing one’s behaviour to produce a favourable impression) are heightened (Mori et al., 1987; Remick, 2010). Similarly, a series of studies have shown that food intake is suppressed when people are made to feel aware that their food intake is being measured in the laboratory (Robinson, Hardman, Halford, & Jones, 2015; Robinson, Kersbergen, Brunstrom, & Field, 2014; Robinson, Proctor, Oldham, & Masic, 2016). Therefore, the effect of any factor that is hypothesised to increase food intake (e.g. increasing the portion size of food) may be systematically underestimated when studied in the laboratory due to heightened self-presentation concerns, suppressing intake from large portions. In support of this hypothesis, meta-analyses indicate that the influence that both portion size and plate size have on food intake tends to be larger in studies that result in participants being less conscious of their food intake (Holden, Zlatevska, & Dubelaar, 2016; Zlatevska et al., 2014).

Although a number of studies have examined the influence of portion size on food intake outside of the laboratory in real-world settings (Diliberti et al., 2004; French et al., 2014; McCrickerd et al., 2017; Vermote et al., 2018), we are unaware of any studies that have directly compared the influence of an external factor on food intake, such as portion size, in laboratory versus real-world settings using the same procedure, participants and test foods. In the present research we conducted two studies to examine whether the influence of the portion size effect on food intake differs between environments. In Study 1, we directly compared the influence of portion size on snack food intake when food intake was examined in a standard laboratory setting versus at home. In Study 2, we compared the influence of portion size on snack food intake when examined in a standard laboratory setting versus in a semi-naturalistic laboratory designed to resemble a lounge setting. In both studies, we hypothesised that the influence of portion size on food intake would be larger when studied in naturalistic or semi-naturalistic settings versus in the standard laboratory.

1. **Study 1**
	1. *Method*

*2.1.1 Design.*

The study used a mixed design with a within-subjects independent variable of environment (standard laboratory, real-world), and a between-subjects independent variable of portion size (small, large). The order of environment was counterbalanced, and a one-week wash out period was implemented between the two sessions. Participants were randomly allocated to the portion size condition and order of environment, sequenced by an online random number generator (https://www.random.org/sequences/). A cover story was used to reduce awareness that food intake would be measured. Specifically, participants were told that the aim of the study was to investigate experiences of a new snack food product when consumed in different eating contexts.

*2.1.2 Participants.*

As there have been no previous studies which have investigated the magnitude of the portion size effect in real-world versus laboratory environments, we powered to detect a medium sized environment by portion size interaction effect (*f* = 0.26) using G\*Power 3.1 (Faul, Erdfelder, Buchner & Lang, 2009). In a mixed design with 80% power and an alpha level of 5%, 64 participants were required for adequate power. We predicted that the difference in food intake between portion sizes would be greater in the real-world compared with the laboratory setting. Eligibility criteria were that participants had to: be aged 18 or over, not be currently dieting, like sweet-flavoured popcorn (as this was the test food), be regular afternoon snack consumers, and have no history of food allergies or intolerances. In total, 68 participants were recruited through word-of-mouth and online advertisements. Posters were displayed across the University campus, predominantly to a student and staff population. Eight participants were excluded from all analyses; four did not complete both testing sessions and four reported that they were currently dieting at the end of the study. This resulted in a final sample of 60 participants (16 male) aged between 21 – 71 years (mean = 31.98, SD = 11.01). Forty percent of the sample were females with a BMI below 25. Thirty-two participants were randomized to the small portion size condition and 28 were randomized to the large portion size condition. The study was approved by the University of Liverpool Institute of Psychology, Health and Society Research Ethics Committee.

*2.1.3 Procedure.*

Test sessions took place on weekdays between 14:00 and 17:00 and lasted approximately 40 minutes each. To standardize appetite, participants were instructed to abstain from eating for at least 2 hours prior to the beginning of each test session. Participants provided informed consent on arrival at the first session and were randomized to complete their first session in the standard laboratory or at home. In the standard laboratory environment, participants were asked to complete an initial questionnaire (to record the time, session location, and whether they had complied with instructions to abstain from eating for 2 hours) and a baseline hunger rating. Next, participants were presented with the popcorn and were informed that they could consume as much popcorn as they liked and to stop eating once the TV clip had ended. The researcher began the TV clip and left the participant alone, returning once the clip had finished. The experimenter then removed the remaining popcorn and participants completed the taste perception ratings, a second hunger rating, and the mood ratings. In the real-world condition, participants collected their study materials (DVD, popcorn, questionnaire pack, and instructions) from the experimenter on the morning of the test session. The order of tasks was the same as in the standard laboratory condition. Upon completion of the real-world session, participants returned the study materials to the experimenter the next morning. A week later, participants completed the second session at the same time of day as the first. At the end of the second session participants completed the TFEQ, awareness check, the popcorn liking rating, portion size perception measure, environment comparison questions, awareness of measurement questions, and recorded whether they complied with the real-world condition instructions – participants who completed the real-world condition in their second session did this after returning the study materials to the experimenter. Weight and height were then measured in the laboratory by the experimenter. Participants were then debriefed and reimbursed for their time.

*2.1.4 Test Settings.*

 *TV clips:* In each setting (standard laboratory and real-world), participants consumed popcorn while watching TV. Two episodes of the comedy TV show ‘Friends’ were used (S10 E07, S10 E08, each approximately 23 minutes in duration). Participants watched these episodes while consuming the popcorn to generate a more naturalistic eating experience and to prevent participants from experiencing feelings of boredom during consumption. Participants were instructed to consume the popcorn only during this period. The order in which participants watched the clips was counterbalanced.

*Standard Laboratory:* The standard laboratory was on the University of Liverpool campus. Participants completed the session alone in a testing booth consisting of a single chair and small table, located in a larger laboratory space with individual testing booths separated by partition screens. Participants were tested individually. The experimenter was in a separate adjacent room during the session and participants notified the experimenter if they required assistance and when they had finished each section of the session by pressing a buzzer. Participants watched the DVD on a laptop with headphones, on the table of the booth. After each section of the session was completed, the experimenter came into the test room to explain to the participant how to complete the next part of the session.

*Real-world:* Participants were provided with a DVD copy of the TV clip and were told to complete the session alone in their home without any distractions and were provided with full instructions of how to complete the test session. See section 7.1 of the supplementary materials for the full study instructions given to participants.

*Test Food.*

Participants received a serving of Butterkist cinema-style sweet popcorn (5.26 kcal per gram) in a large, clear bag. Participants either received a 100 g (small portion condition) or 200 g (large portion condition) serving of popcorn. The portion sizes were selected to be consistent with other studies which have implemented a 100% increase between portion size conditions (Burger, Fisher, & Johnson, 2011; Sheen, Hardman & Robinson, 2018). Piloting of the portion sizes indicated that very few participants would be likely to finish either the small or large popcorn serving, therefore avoiding a ceiling effect of food intake. Popcorn caloric intake in each session was measured by subtracting the post-consumption weight from the pre-consumption weight of the bag of popcorn and multiplying this by the popcorn’s caloric density.

*2.1.5.* *Measures.*

*Taste Perception and Mood Ratings:* To bolster the cover story, participants completed a 15-item questionnaire where they rated the popcorn on different sensory properties (e.g. sweet) on a 100-mm visual analogue scale (VAS) with the anchors of “Not at all” to “Extremely”. Participants also completed 16 mood rating questions measured using a Likert scale (1 = “definitely do not feel” to 5 = “definitely feel”).

*Eating restraint and disinhibition:* In order to characterize the sample, participants completed the restraint (scored out of 21) and disinhibition (scored out of 16) sub-scales of the Three-Factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985) as these have been shown to be associated with snack food intake (Robinson et al., 2017). See Table S1 of the supplementary materials for means and standard deviations.

*Hunger*: Hunger ratings (Blundell et al., 2010) were assessed using a 100-mm VAS with anchors ‘Not At All’ and ‘Extremely’. These were taken at baseline and immediately after consumption of the popcorn. See Table S2 of the supplementary materials for means and standard deviations of post-consumption hunger ratings.

*Liking of popcorn:* Participants rated how much they liked the popcorn using a 100-mm VAS with ‘Not at all’ and ‘Extremely’ as anchors.

*Perception of portion size:* Participants gave their opinion of the portion size they received on a 7-point Likert scale (1 = ‘Too Large’ to 7 = ‘Too Small’). This measure was used as a manipulation check.

*Environment comparisons*: Participants were asked in which environment: they felt more relaxed whilst eating the popcorn; consuming the popcorn felt more naturalistic; they ate more of the popcorn in. Options were: ‘In the lab’, ‘At home’ and ‘No difference’.

*Awareness of measurement:* Participants were also asked the extent to which they felt as though the researcher would measure how much they were eating when eating the popcorn in the standard laboratory and in the real-world environment, on separate 7-point Likert scales (1 = ‘Strongly Agree’, 7 = ‘Strongly Disagree’).

*2.1.6 Data Analysis.*

A 2x2 mixed ANOVA was conducted, with portion size (small, large) as a between-subjects factor and environment (standard laboratory, real-world) as a within-subjects factor and caloric intake as the dependent variable. Follow-up pairwise comparisons were conducted to test whether food intake differed between environments at each level of portion size, and to test whether food intake differed between portion sizes, separately within each environment. The effect size reported for these comparisons was Cohen’s d, whereby 0.2 = a small effect size; 0.5 = medium effect size; 0.8 = large effect size (Cohen, 1988). To determine the potential impact of demand characteristics, participants were coded as being aware of the study aims if they mentioned the effect of portion/serving size on amount consumed, the effect of environment/eating context/setting on amount consumed, or whether the effect of portion size on amount consumed is influenced by the eating environment. This was measured at the end of the second session. Responses were independently coded by two researchers. Any disagreements between researchers was resolved through discussion.

2.2. *Results*

*2.2.1. Participant characteristics.*

See Table 1 for participant characteristics.

Table 1. Participant characteristics split by portion size condition (mean ± SD unless stated otherwise).

|  |  |  |
| --- | --- | --- |
|  | Small (N = 32) | Large (N = 28) |
| Gender (F/M) | 23F/9M | 21F/7M |
| Age (years) (range) | 32.13 ± 11.52 (21 – 71) | 31.82 ± 10.60 (21 – 63) |
| BMI (kg/m2) | 23.84 ± 3.42 | 25.40 ± 4.05 |
| Baseline Hunger (0-100mm: Standard Laboratory) | 58.03 ± 20.87 | 54.09 ± 22.03 |
| Baseline Hunger (0-100mm: Real-world) | 57.45 ± 20.87 | 55.21 ± 18.35 |
| Liking of Popcorn (0-100mm) | 76.45 ± 14.94 | 67.46 ± 19.90 |

BMI (body mass index) = measured weight (kg) / height (m)2.

*2.2.2 Effect of environment and portion size on consumption*

There was a significant main effect of environment on energy intake *F*(1,58) = 14.65, *p* < .001, ƞp2 = .20, with participants consuming a significantly greater amount of popcorn in the real-world condition relative to the standard laboratory condition (Figure 1a). There was also a significant main effect of portion size on energy intake *F*(1,58) = 11.17, *p* = .001, ƞp2 = .16, with participants in the large portion condition consuming more popcorn compared to the small portion condition (Figure 1b). Importantly, there was a significant portion size by environment interaction *F*(1,62) = 4.39, *p* = .02, ƞp2 = .09. Follow-up paired samples t-tests revealed that food intake did not differ between environments when consuming a small portion size *t*(31) = 1.21, *p* = .24, *d* = 0.15, but food intake did differ between environments when consuming a large portion size *t*(31) = 3.71, *p* = .001, *d* = 0.70. Independent samples t-tests revealed that there was a larger portion size effect in the real-world *t*(39.49) = 3.68, *p* = .001, *d* = 0.97 compared with the standard laboratory *t*(43.03) = 2.21, *p*  = .04, *d* = 0.56.

\*

\*

\*

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**A**

**B**

Figure 1. Mean caloric popcorn intake by environment and portion size (Study 1). Figure 1a displays food intake with environment along the x-axis. Figure 1b displays portion size along the x-axis. Error bars represent the standard error of the mean. \* p < .05. Numbers in bars represent the sample size for each cell.

*2.2.3 Perception of portion size*

Participants in the small portion condition rated the portion of popcorn to be significantly smaller than in the large condition *t*(58) = 2.97, *p* = .004, *d* = 0.77.

*2.2.4 Awareness of measurements*

There was no significant difference in the extent to which participants reported that they felt that the researcher would measure food intake between the standard laboratory and real-world setting, *t*(59) = 1.41, *p* = .16, *d* = 0.13.

*2.2.5* *Environmental comparisons*

A chi-square goodness of fit test revealed that participants’ responses of where they felt most relaxed differed significantly from chance expectation of frequency distribution χ2(2) = 38.10, *p* < .001. The observed frequency of ‘In the lab’ was significantly lower than the expected frequency (*p* < .001), but the observed frequency of ‘At home’ was significantly greater than the expected frequency (*p* < .001). However, the observed frequency of ‘No difference’ did not significantly differ from the expected frequency (*p* = .99).

Similarly, participants’ responses of where eating the popcorn felt more naturalistic differed significantly from chance expectation frequencies χ2(2) = 58.90, *p* < .001. The observed frequency of ‘In the lab’ was significantly lower than the expected frequency (*p* < .001), but the observed frequency of ‘At home’ was significantly greater than the expected frequency (*p* < .001). However, ‘No difference’ did not differ (*p* = .88). Lastly, responses of which environment participants ate more of the popcorn differed significantly from expected χ2(2) = 11.20, *p* = .004. However, observed frequencies did not differ from expected frequencies for ‘In the lab’ (*p* = .67), ‘At home’ (*p* = .08) or ‘No difference’ (*p* = .61). These findings suggest that participants found the real-world environment more relaxing and naturalistic than the standard laboratory. See Table 2 for counts and sample percentages of each response.

Table 2. Contingency table showing counts and sample percentages of responses for each environmental comparison measure.

|  |  |  |  |
| --- | --- | --- | --- |
|  | I felt more relaxed while eating the popcorn | Eating the popcorn felt more naturalistic | I ate more of the popcorn |
|  | N | % | N | % | N | % |
| In the lab | 1 | 1.7 | 0 | 0.0 | 16 | 26.7 |
| At home | 40 | 66.7 | 47 | 78.3 | 32 | 53.3 |
| No difference | 19 | 31.7 | 13 | 21.7 | 12 | 20.0 |
| Total | 60 | 100.0 | 60 | 100.0 | 60 | 100.0 |

*2.2.6.* *Perception of aims of study (portion size and environment)*

Due to 38 out of 60 participants showing some awareness of the study aims (36 showed awareness of the environment manipulation, one showed awareness of the portion size and one showed awareness of both the portion size and environment manipulation), we explored whether including awareness of study aims as a between-subjects factor affected results. Results remained the same as in the primary analyses. See section 7.4 of the supplementary materials for the analyses.

*2.2.7. Additional Analyses*

To investigate whether controlling for age, gender and BMI affected results reported in section 2.2.2, we conducted the same analysis with the inclusion of age, gender and BMI as co-variates using an ANCOVA. Findings revealed that the main effect of portion size and the portion size by environment interaction remained significant in the same direction, however the main effect of environment became nonsignificant: *F*(1, 55) = 1.24, *p* = .27, ƞp2  = .02.

*2.3 Interim discussion*

Findings of Study 1 indicate that the influence of portion size on snack food intake was moderated by environmental context, whereby altering the portion size had a larger effect on food intake when eating at home compared with eating in the standard laboratory. Planned contrasts revealed that this effect was explained by participants consuming a similar amount of food from the small sized portion in the laboratory versus at home, but participants consumed more food when served the large portion at home versus in the laboratory. Findings also suggest that participants felt more relaxed when consuming the popcorn at home and felt that consuming the popcorn was more naturalistic at home. We speculate that the portion size by environment interaction effect may be driven by self-presentation concerns. Although the extent to which participants felt that their food intake was being measured across environments did not differ, a large proportion of participants reported that they felt more relaxed and felt that eating the popcorn felt more naturalistic when completing the session in their home. This in turn may have reduced self-presentation concerns, which then produced greater levels of food intake when consuming the large portion size in the real-world setting.

The aim of Study 2 was to investigate whether self-presentation concerns differ between a standard versus semi-naturalistic laboratory and to see whether the same portion size by environment interaction could be found using this environmental comparison. We used a semi-naturalistic laboratory rather than a real-world setting to obtain greater experimental control by being able to ensure that participants followed study instructions correctly in both environments. To capture self-presentation concerns, we included a validated measure of public and private self-awareness (Govern & Marsch, 2001). Public self-awareness refers to awareness of how one presents themselves to others. Private self-awareness refers to awareness of one’s own feelings and thoughts. We measured public self-awareness levels to capture and compare self-presentation concerns across environments. Private self-awareness levels were also compared across settings as this type of self-awareness has been shown to increase when primed with an external standard (Kitchens, 2015). We hypothesised that the same portion size by environment interaction as found in Study 1 would be observed in Study 2, and that participants would feel more self-aware in a standard versus semi-naturalistic laboratory which would explain differences in energy intake between settings.

1. **Study 2**
	1. *Method*

*3.1.1 Participants*

We powered Study 2 based on the results of Study 1 (see section 7.6 of the supplementary materials). Study 2 used the same cover story as in Study 1. In total, 65 participants were recruited using the same recruitment strategy as in Study 1. Six participants were excluded from all analyses; one did not complete both sessions and five indicated that they were currently dieting. The final sample of 59 participants (male = 20) was aged between 19 – 63 years (mean = 28.12, SD = 8.87). Forty one percent of the sample were females with a BMI below 25. Thirty were randomized to the small portion size condition and 29 were randomized to the large portion size condition. Eligibility criteria were the same as in Study 1 with the following additions: participants from Study 1 were ineligible, as was anyone based in the same building as the laboratories. The study was approved by the University of Liverpool Institute of Psychology, Health and Society Research Ethics Committee. The method and analysis strategy for this study was pre-registered on the Open Science Framework (protocol and data available at: <https://osf.io/rfu4c/>).

*3.1.2 Design*

The same study design was used with the exception that we stratified for gender in Study 2, as men tend to consume more food than women in an *ad libitum* eating setting (Robinson et al., 2017). Separate randomly allocated sequences were generated within each gender to achieve an equal proportion of men and women in both portion size conditions.

*3.1.3 Test Settings*

*TV clips:* The same as in Study 1.

*Standard Laboratory:* The same laboratory was used as in Study 1.

*Semi-naturalistic Laboratory:* The semi-naturalistic laboratory (located in the same building as the standard laboratory) was furnished with a sofa, coffee table, bookcase, lamp, television and rug, to appear similar to a living room. Participants were informed that the experimenter would remain in a separate adjacent room separated by a closed door during the session. Participants watched the TV clip on a laptop, wearing headphones.

*Test Food*: The same test food was used as in Study 1.

*3.1.4 Materials*

*Taste Perception and Mood Ratings:* These measures were used to bolster the cover story as in Study 1. The measures were the same apart from mood ratings, which in Study 2 was assessed using the Positive and Negative Affect Schedule (PANAS; Watson, Clark & Tellegen, 1988); a self-report scale comprising of two 10-item subscales measuring positive and negative affect. Each item was rated on a 5-point scale from 1 (not at all) to 5 (very much).

*Initial questionnaire, hunger ratings, eating restraint and disinhibition:* These measures were taken to characterise the sample and were the same as in Study 1. See Table S3 and S4 of the supplementary materials for restraint and disinhibition scores, and post-consumption hunger ratings, respectively.

*Self-awareness:* Participants completed the ‘public’ and ‘private’ sub-scales of the Situational Self-Awareness Scale (SSAS; Govern & Marsch, 2001). The sub-scales were modified such that participants retrospectively rated self-awareness scores during consumption of the popcorn. The public subscale measured attentiveness to features of the self that are presented to others (e.g., ‘Whilst watching the DVD I was concerned about the way I presented myself’). The private sub-scale measured attentiveness to internal aspects of the self (e.g., ‘Whilst watching the DVD, I was conscious of my inner feelings’). Each sub-scale consisted of three items rated on 7-point Likert scales from 1 (‘Strongly disagree’) to 7 (‘Strongly agree’) which were summed to produce total scores.

*Public situational self-awareness of eating behaviour:*

Three questions were adapted from the public subscale of the SSAS to measure attentiveness of one’s self-presentation to others specifically in relation to eating behaviour (e.g. ‘Whilst watching the DVD, I was concerned about how the amount of food I was consuming would affect how I presented myself’). Responses were provided on 7-point Likert scales from 1 (‘Strongly disagree’) to 7 (‘Strongly agree’), which were summed to produce a total score.

A*ppropriateness of consumption:*

Participants rated the appropriateness of eating a large amount of food (‘It felt appropriate to eat a large amount of food’; ‘It only felt appropriate to eat a small amount of food’) on separate 7-point Likert scales from 1 (‘Strongly disagree’) to 7 (‘Strongly agree’). This questionnaire was self-devised by the authors.

*3.1.5. Procedure.*

Participants attended two 40-50-minute sessions on weekdays between 14:00 and 17:30, with a two-week washout period between sessions. The procedure was identical to Study 1 except for the setting and that in both sessions participants completed the PANAS instead of the mood questionnaire, followed by completion of the SSAS, public self-awareness of eating behaviour, and appropriateness of consumption measures. Participants did not complete the liking of popcorn measure, perception of portion size measure, environment comparisons measure or awareness of measurement questions as described in Study 1.

*3.1.6 Data Analysis*

We used the same analysis approach as in Study 1 with the addition of conducting paired sampled t-tests to investigate environment effects on each measure of self-awareness and both appropriateness of consumption measures.

*3.2 Results*

See Table 3 for participant characteristics.

Table 3. Participant characteristics for small and large portion condition. Values are mean ± SD unless stated otherwise.

|  |  |  |
| --- | --- | --- |
|  | Small (N = 30) | Large (N = 29) |
| Gender (F/M) | 20F/10M | 19F/10M |
| Age (years) (range) | 29.53 ± 9.86 (19 – 63) | 26.66 ± 7.62 (20 – 37) |
| BMI (kg/m2)1 | 23.43 ± 5.26 | 25.66 ± 7.76 |
| Baseline Hunger (0-100mm; Standard Laboratory) | 56.23 ± 21.27 | 52.97 ± 21.32 |
| Baseline Hunger (0-100mm; Semi-Naturalistic Laboratory) | 55.93 ± 20.14 | 57.79 ± 18.18 |

Note: 1 due to a recording error, BMI is missing for 3 participants. BMI (body mass index) = measured weight (kg) / height (m)2 .

*3.2.1 The effect of environment and portion size on consumption*

A 2 (environment; semi-naturalistic laboratory, standard laboratory) x 2 (portion size; small, large) mixed ANOVA revealed a nonsignificant main effect of environment *F*(1,57) = 0.22, *p* = .64, ηp2 < .01, a nonsignificant main effect of portion size *F*(1,57) = 4.02, *p* = .05, ηp2 = .07, and a nonsignificant environment by portion size interaction *F*(1,57) = 0.02, *p* = .90, ηp2 < .01 (Figure 2).

Figure 2. Mean caloric popcorn intake split by environment and portion size (Small, Large). Error bars represent the standard error of the mean. Numbers in bars represent sample size for each cell. Interaction and main effects were all nonsignificant.

*3.2.2 The effect of environment on self-awareness and appropriateness of consumption.*

Paired-samples t-tests revealed that public self-awareness did not differ between environments *t*(58) = -1.96, *p* = .06, *d* = 0.18, nor did food-related public self-awareness *t*(58) = -0.90, *p* = .37, *d* = 0.08 (Table 4). However, private self-awareness scores were significantly greater in the standard laboratory, compared with the semi-naturalistic laboratory *t*(58) = -2.88, *p* = .006, *d* = 0.27. Perceived appropriateness to consume a large amount did not differ between environments *t*(58) = .069, *p* = .95, *d* = 0.01, nor did perceived appropriateness to consume a small amount *t*(58) = 1.22, *p* = .23, *d* = 0.11.

Table 4. Self-awareness and appropriateness of consumption scores, split by environment. Values are mean ± SD.

|  |  |  |
| --- | --- | --- |
|  | Standard Laboratory (N = 59) | Semi-Naturalistic Laboratory (N = 59) |
| Public Self-awareness (out of 21) | 7.68 ± 4.80 | 6.53 ± 3.38 |
| Private Self-awareness (out of 21) | 9.32 ± 4.12 | 8.00 ± 3.69 |
| Public self-awareness of eating behaviour (out of 21) | 10.54 ± 5.14 | 9.97 ± 4.94 |
| Appropriateness of consumption: small (out of 7) | 3.02 ± 1.50 | 2.73 ± 1.48 |
| Appropriateness of consumption: large (out of 7) | 4.23 ± 1.63 | 4.22 ± 1.64 |

*3.2.3* *Perception of aims of study (portion size and environment):*

Similarly to Study 1, a large proportion of participants showed some awareness of the study aims (44/59; one was aware of the portion size manipulation, 43 were aware of the environment manipulation). As in Study 1, we explored whether including awareness of study aims as a between-subjects factor affected results. Results remained the same as in the primary analyses. See section 7.9 of the supplementary materials for full analyses.

*3.2.4 Additional Analyses*

As in Study 1, we conducted the same analysis as in section 3.2.1 with the inclusion of age, gender and BMI as co-variates, creating an ANCOVA. The main effects of portion size and environment, and the portion size by environment interaction remained nonsignificant.

1. **Discussion**

In the present research, we examined whether the context in which eating behaviour is measured, impacts the influence of portion size on food intake. In Study 1, we found evidence indicating that portion size had a larger influence on food intake when participants ate at home compared to a standard laboratory setting. These findings suggest that standard laboratory settings may underestimate the impact that portion size has on food intake in every-day life. In Study 2, we next compared the effect of portion size on food intake in a standard laboratory versus a semi-naturalistic laboratory designed to resemble a home setting in order to have greater experimental control as compared with the real-world setting in Study 1. However, in this study we did not find evidence that the influence of portion size on food intake was dependent on laboratory type.

In Study 1, a large proportion of participants reported feeling more relaxed when eating at home compared to in the standard laboratory condition. In Study 2 we did not measure this, but instead measured situational self-awareness. Ratings of public self-awareness did not differ between the standard and semi-naturalistic laboratory settings, suggesting that self-presentation concerns were similar across environments. There was evidence that participants experienced greater private self-awareness in the standard laboratory, which is indicative of greater awareness of one’s thoughts and feelings (Govern & Marsch, 2001), but self-awareness of eating behaviour did not vary by laboratory setting. Collectively, these findings tend to suggest that the semi-naturalistic laboratory was perceived to be broadly similar to the standard laboratory. This may be attributable to the location of both laboratories being in a research building and that both sessions involved close interaction with the experimenter, factors which may have heightened self-presentation concerns compared to when eating at home. Directly comparing self-presentation concerns and eating behaviours between a standard laboratory, semi-naturalistic laboratory and real-world setting in the same study would be beneficial in establishing how these settings produce difference behaviours from one another.

There are several strengths to the present research. By using nearly identical procedures in the different laboratory and real-world experimental conditions, we were able to directly examine the influence of portion size across different experimental contexts in the same participants, which is not permitted by comparing results of separate existing studies in different environments. The cover story and probing of participant awareness of study aims helped to rule out demand characteristics as a potential explanation of findings (Kersbergen, Whitelock, Haynes, Schroor, & Robinson, 2019; Sharpe & Whelton, 2016). Study 2 was pre-registered and based on the effect sizes found in Study 1, was sufficiently powered to detect the portion size by environment interaction effect. A limitation of Study 1 is that although we provided participants with detailed study instructions and assessed self-reported compliance, we cannot rule out that some participants ate the study food before or after the allotted experimental session, which may explain the higher food intake observed in the real-world (home) condition. However, we presume this would be unlikely to account for the interaction between portion size and environment observed in Study 1. Replication of the findings of Study 1 with objective measurement of adherence to study protocols during out-of-laboratory eating would therefore be valuable.

There were also additional limitations to the present studies. Firstly, in both conditions across the two studies, participants consumed the snack food whilst in a distracted state (i.e., watching television). Television viewing has been shown to induce ‘mindless eating’ and increase food intake (Bellissimo et al., 2007; Blass et al., 2006). Therefore, findings may have differed if the popcorn was consumed in a setting without distraction. Secondly, we measured food intake during a single session for each experimental condition. Given that the laboratory is likely to be a relatively novel and unfamiliar eating setting, it is plausible that if we had repeatedly measured food intake, our findings could differ. For example, after several laboratory sessions participants may feel less self-conscious of their food intake in the laboratory and eat more similarly to how they would do so in the real-world. Relatedly, both studies only measured acute eating behaviour, and therefore does not investigate whether individuals may later compensate for the amount of food consumed in the test session. An additional limitation is that we predominantly tested females in both studies. Research suggests that avoiding excessive food consumption is an impression management strategy more commonly found in females than males (Mori et al., 1987; Pliner & Chaiken, 1990; Remick, 2010), therefore future studies may wish to investigate whether this environmental effect on portion size is gender-specific. Furthermore, findings have shown that the portion size effect is larger in males compared with females, and is greater in individuals with a BMI of 25 or less, compared with a BMI greater than 25 (Zlatevska et al., 2014). Therefore, as samples in both studies consisted of a relatively large number of females with a lean BMI, findings may not generalise to individuals who differ on these characteristics. Future research may wish to specifically test for subgroup differences when comparing real-world and laboratory-based observations of the portion size effect. Lastly, the present findings cannot be generalised to the consumption of other foods and other eating occasions. Generally, more energy intake is consumed during main meals than snacks (Ovaskainen et al., 2006), and although increasing the portion size of both snack and non-snack foods increases intake (Zlatevska et al., 2014), non-snack foods are influenced to a lesser extent. Therefore, consumption of non-snack foods may produce different results to the present findings.

If future research replicates the present findings, then there are likely to be important implications. The relative size of influence that external factors, such as portion size, are thought to have on food intake impact the interpretation of their theoretical importance and whether or not they are pursued as targets for public health intervention. As an illustrative example, there is very mixed evidence on the impact that menu energy labelling has on food choice and energy intake. This may be partially due to energy labelling having been studied in both the laboratory and real-world settings (Bleich et al., 2017; Crockett et al., 2018; Littlewood, Lourenço, Iversen, & Hansen, 2016). Specifically, study conclusions differ based on whether testing has been conducted in the laboratory versus the real-world, with some reviews suggesting greater effectiveness of energy labelling in laboratory settings (Long, Tobias, Cradock, Batchelder, & Gortmaker, 2015). Similarly, further research on the portion size effect is needed in real-world settings in order to effectively direct policy making (Almiron-Roig et al., 2020). For eating behaviour research to accurately guide public health policy in general, it is therefore important that we do not rely on laboratory measures alone. In particular, the influence of portion size on eating has primarily been studied in the laboratory to date and the present findings highlight the need to study the influence that external factors, such as portion size, have on eating behaviour in the real-world. Findings from Study 1 add to previous literature which has established that the portion size effect occurs in real-world settings (Diliberti et al., 2004; McCrickerd et al., 2017), but also suggests that individuals may be affected by changes to portion sizes more so in real-world settings compared to the laboratory. As most eating occurs in the home setting (Ziauddeen et al., 2018), interventions to reduce the portion sizes of energy dense food consumed in the home are likely to benefit public health.

In Study 2, participants experienced higher private self-awareness in the standard laboratory than the semi-naturalistic laboratory. However, there was no evidence to suggest that the portion size effect was reduced in the standard relative to the more naturalistic setting, as in Study 1. Because a number of studies have made use of semi-naturalistic eating laboratories (Hermans, Herman, Larsen, & Engels, 2010; Marsh, Mhurchu, Jiang, & Maddison, 2014; Wonderlich-Tiernet, Wenzel, Vander Wal & Wang-Hall, 2013), it would now be informative to examine whether eating behaviour (and associated influences) in these settings more closely resembles how people eat in the real-world compared to more traditional laboratory settings. This may inform whether the costs and inconvenience of converting existing laboratory facilities is worthwhile.

1. **Conclusions**

The impact that external factors, such as portion size, have on food intake in the real-world may be underestimated when studied in standard laboratory settings. However, we did not find evidence to suggest that the effect of portion size differed between standard and semi-naturalistic laboratory settings.

**Availability of data and materials.** The study datasets for Study 1 and Study 2 and registered protocol for Study 2 is available on the Open Science Framework repository at <https://osf.io/rfu4c/>

**Competing interests.** ER has previously received research funding from the American Beverage Association and Unilever for projects unrelated to the present work. CAH has previously received research funding from the American Beverage Association and speaker fees from the International Sweeteners Association for projects unrelated to the present work.

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