Socioeconomic status and the susceptibility to overeat from excessive food portions

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Abstract

Objectives: Socioeconomic status is one of the strongest predictors of obesity, and of living in deprived neighborhoods with unhealthy food environments. Little is known, however, about the psychological processes that translate features of such environments into health inequalities. One important feature of unhealthy food environments is the prevalence of excessive portions of energy-dense food. The present study tested whether those with lower socioeconomic status are particularly susceptible to overeat from large portions, and examined the psychological processes underlying this susceptibility. **Methods:** A large-scale online experiment was conducted in which participants ($N = 511$) indicated how much they would eat from small and large portions of low and high energy-dense snacks. Perceptions of how much was considered appropriate to eat, and trait impulsiveness were also assessed. **Results:** Participants with lower socioeconomic status were especially likely to eat more from large compared to small portions of the high energy-dense snacks, equivalent to a 15-22% increase in calorie intake. These effects were mediated by perceptions of how much is appropriate to eat, and by trait impulsiveness. **Conclusions:** These findings point to a significant double health burden of low socioeconomic status: those with a lower socioeconomic status are disproportionately exposed to unhealthy food environments, and specific psychological processes predispose them to overeat when exposed to those environments. This study critically informs the emerging understanding of the psychology of health inequalities.

Keywords: health behavior, eating behavior, socioeconomic status, health inequalities, open data

Socioeconomic status is one of the strongest predictors of obesity (e.g., Darmon & Drewnowski, 2008). The prevalence of obesity in England, for example, is 45% lower for women with the highest household incomes than with the lowest incomes, and 47% lower for women with degree-level qualifications than with no qualifications (Moody & Neave, 2015; Roberts, Cavill, Hancock, Rutter, 2013). Socioeconomic status is also a strong predictor of living in deprived neighborhoods with unhealthy food environments. More deprived areas have an increased density of fast-food outlets, and therefore increased access to excessive portions of attractive, energy-dense food (e.g., Burgoine et al., 2016). This leads to two important questions: (1) How do people with lower socioeconomic status respond to such food environments? and (2) What are the psychological processes that translate features of food environments into health inequalities?

Previous work has typically studied the associations of socioeconomic status with food environments and health inequalities separately, without examining the psychological processes that link them. The present study brings those areas together and tests whether individuals with lower socioeconomic status are particularly susceptible to overeat from large portions of energy-dense food. Furthermore, the present study tests the hypotheses that increased impulsivity and perceptions of how much is appropriate to eat underlie this effect, and are therefore central psychological processes contributing to health inequalities. The present work identifies a significant double health burden of low socioeconomic status: those with a lower socioeconomic status are disproportionately exposed to unhealthy food environments, and specific psychological processes predispose them to overeat when exposed to those environments.

One central feature of unhealthy food environments is the availability of excessive portions of energy-dense food. Food portions, especially those from fast-food outlets, have grown substantially in recent decades (e.g., Young & Nestle, 2012). Most people overeat when presented with a large compared to a small portion of food, a phenomenon known as the ‘portion-size

effect’ (for meta-analyses, see Hollands et al., 2015; Zlatevska, Dubelaar, & Holden, 2014). The portion-size effect is especially pronounced – and especially problematic – for energy-dense food (e.g., Hollands et al., 2015). As a result, excessive portions of energy-dense foods have been identified as playing a key role in the current obesity crisis (Marteau, Hollands, Shemilt, & Jebb, 2015). Importantly, the present study tests the hypothesis that this is especially true for people with a lower socioeconomic status. The present study also examines whether that exposure to excessive portions contributes to increasing health inequalities via individual differences in impulsivity, and through altering perceptions of how much is appropriate to eat.

Impulsivity jointly refers to the inabilities to suppress responses to short-term rewards in favor of greater longer-term rewards and to stop oneself from responding to tempting stimuli. Lower socioeconomic status has been associated with increased impulsivity and reduced response inhibition (e.g., Hackman, Farah, & Meaney, 2010). Indeed, the experience of deprivation and inequality may increase engagement in risky and impulsive behaviors (Haushofer & Fehr, 2014; Payne, Brown-Iannuzzi, & Hannay, 2017). Higher trait impulsivity has also been associated with increased consumption of energy-dense food (e.g., Guerrieri, Nederkoorn, & Jansen, 2008). It was therefore hypothesized that, in the face of large portions of attractive, energy-dense food, higher impulsivity could explain the increased susceptibility for overconsumption amongst those with lower socioeconomic status.

Furthermore, lower socioeconomic status could also increase the susceptibility to overeat from excessive portions by altering perceptions of how much is appropriate to eat. Appropriateness has been found to play an important role in the portion-size effect, such that the size of a served portion or food package acts as a cue for how much is ‘appropriate’ or socially acceptable to eat. As a result of these normative processes, consumption increases when larger portions are available, especially if the food is attractive (e.g., Versluis & Papies, 2016a). People living in more deprived

neighborhoods are regularly exposed to larger portions of energy-dense food (e.g., Burgoine et al., 2016), and those with lower socioeconomic status consume more energy-dense food in general (e.g., Darmon & Drewnowski, 2008; Pechey et al., 2013). These experiences may make larger portions of energy-dense food seem ‘normal’ and overconsumption from these portions seem appropriate (Robinson & Kersbergen, 2018). Thus, it is possible that perceptions of how much is appropriate to eat drive the increased susceptibility for overconsumption amongst those with lower socioeconomic status.

In the current study, an online methodology was used to obtain a large sample of participants from a wide range of socioeconomic backgrounds. In a previously validated paradigm (see Robinson, Te Raa, & Hardman, 2015), participants were presented with images of various low and high energy-dense snacks, and how much they would eat from each was measured. Trait-level impulsivity, and how much participants thought would be appropriate to eat from each food were also assessed. Four measures of socioeconomic status were then obtained. Participants reported their highest educational qualification and current household income. Participants also reported their household postcode, which was linked to the English Index of Multiple Deprivation (Smith, Noble, Noble, Wright, & McLennan, 2015). This serves to index geographic neighbourhood deprivation, which has been shown to predict obesity prevalence and the density of fast-food outlets. Finally, participants reported their perceived current wealth as subjective socioeconomic status has been shown to be a strong predictor of various health outcomes (for a recent meta-analysis, see Cundiff & Matthews, 2017).

It was hypothesized that intended consumption would be higher from larger than from smaller portions, especially for energy-dense snacks, replicating earlier findings (see meta-analyses, Hollands et al., 2015; Zlatevska, Dubelaar, & Holden, 2014). More importantly, it was predicted that this pattern would be especially pronounced amongst those with a lower socioeconomic status.

It was further hypothesized that this effect would be mediated by trait impulsivity, and by perceptions of how much is appropriate to eat.

Method

Design

The experiment had a 2 (portion size: small vs. large) $\times$ 2 (snack energy-density: low vs. high) within-participants design. The socioeconomic status of each participant was operationalized as a discrete categorical variable for highest educational level (low vs. high) and as continuous variables for household income, area-level neighborhood deprivation, and perceived current wealth. Participants viewed half of the food items in a small portion size and the other half in a large portion size. The mapping between each food item and portion size was counterbalanced across participants. Participants were not informed about the portion-size manipulation.

Participants

530 adults from the general population were recruited through the online platform Prolific Academic. Following exclusions, there were 511 participants for all analyses, except for household income where further exclusions resulted in a sample of 504 participants (for details, see Footnote 1). The target sample size and exclusion criteria were decided in advance of data collection. An *a priori* power calculation was performed using G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2009). Although multilevel models were the planned analysis, a power calculation was performed for a standard linear regression to approximate the required sample size. Cohen's f^2 of 0.02,

¹ Participants were excluded from the data analyses when they reported having a food allergy ($N = 2$), reported experiencing technical problems ($N = 6$), or provided an incomplete or invalid postcode ($N = 11$). Seven additional participants were excluded from the analyses of household income because they did not provide a response to this question ($N = 6$) or because they provided an unusually high income and thus were identified as an outlier in box-plot analyses ($N = 1$). Thus, there were 511 participants for all analyses, except those with household income where there were 504 participants.

corresponding to a ‘small’ effect, was defined as the minimally-interesting effect size since there was no previous research on which an informed effect-size estimate could be based. With 80% power and $p < 0.05$, it was determined that a minimum sample size of 485 participants was required to detect an effect of socioeconomic status on the portion-size effect (i.e. large portions minus small portions) for intended consumption of the energy-dense snacks.

Participants received monetary compensation in return for their participation (£1.50). Eligible participants were 18-70 years and were currently living in England (a full list of exclusion criteria is presented in the Supplemental Materials).

This experiment was approved by the local research ethics committee at the Institute of Neuroscience and Psychology, University of Glasgow (application no.: 300170007). Informed consent was obtained after the nature and possible consequences of the study were explained. Participants could withdraw at any time during study completion.

Sample Characteristics

Table 1 presents the study sample characteristics. The present sample was largely comparable to the general population in England and Wales on several key characteristics. For example, the sample household income was comparable to the mean average household income across England and Wales before tax or other deductions (£37, 270; Office for National Statistics, 2018), the sample area-level neighborhood deprivation closely matched the mean neighborhood deprivation across all areas in England (21.67; range: 0.48-92.60; based on the English Index of Multiple Deprivation score; Smith, Noble, Noble, Wright, & McLennan, 2015), and the sample body mass index (kg/m²; BMI) was comparable to the mean BMI across England (27.4 kg/m²; Fuller, Mindell, & Prior, 2017). Note, however, that the present sample was more educated than the general population in which 27% of adults living in England and Wales reported having a undergraduate degree or above in the 2011 census (Office for National Statistics, 2013).

<i>Characteristic</i>	<i>N</i>	<i>%</i>
Gender		
Female	341 (67)	67
Male	170 (33)	33
Highest Educational Qualification		
No formal qualifications	6 (1)	1
Secondary school (e.g., GCSEs or equivalent)	116 (23)	23
College (e.g., A-levels, AS-levels, vocational qualification, or equivalent)	172 (34)	34
Undergraduate degree (e.g., BA, BSc, or equivalent)	155 (30)	30
Graduate degree (e.g., MA, MSC, MPhil, or equivalent)	47 (9)	9
Doctoral degree (e.g., PhD or equivalent)	15 (3)	3
	<i>M</i>	<i>SD</i>
Age (years)	37.81	27.15
Pre-Tax Household Income (GBP)	35,931.24	25,965.91
Neighborhood Deprivation	24.81	16.47
BMI (kg/m²)	27.49	6.88
Self-reported hunger (0 = not at all hungry; 100 = extremely hungry)	37.81	27.15

Table 1. Sample characteristics. *M* = mean; *SD* = standard deviation

Stimuli

Participants were presented with images of four high energy-dense snacks (fries, crisps, chocolate minstrels, cookies) and four low energy-dense snacks (carrot sticks, cucumber, grapes, blueberries). There were two portion sizes: the ‘small’ portion corresponded to a regular serving (as determined by manufacturer recommendations or by UK National Health Service recommended servings for the high and low energy-dense snacks, respectively). The ‘large’ portion was 2x the small portion to the nearest whole food unit (weights and calorie contents are presented in the Supplemental Materials). Each food was photographed on white plate in both the small and large portion sizes. As a size reference, a standard pen was placed to the right of the plate. The full stimulus set can be accessed here: https://osf.io/6438n/?view_only=c5a5b81c00544590948fc3f878456c49.

Measures of Socioeconomic Status

Highest education level. Education was measured using the question “What is your highest educational qualification?”. Participants selected one of the following options: *No formal*

qualifications, Secondary school (e.g., GCSEs or equivalent), College (e.g., A-levels, AS-levels, vocational qualification or equivalent), Undergraduate degree (e.g., BA, BSc or equivalent), Graduate degree (e.g., MA, MSc, MPhil or equivalent), Doctoral degree (e.g., PhD or equivalent). Participants with qualifications below undergraduate degree were categorized as ‘low educational attainment’ ($N = 294$, 58%); participants with an undergraduate degree or above were classed as ‘high educational attainment’ ($N = 217$, 42%).

Household income. Household income was assessed by asking participants: “What is your annual pre-tax household income, including all earners in your household, in GBP?”. Participants were instructed to enter the full amount, and in the case they lived in a multiple occupancy household, to report only the income that they had personal access to.

Neighborhood deprivation. Neighborhood deprivation was assessed by asking participants to report their full household postcode. Each postcode was linked to the English Index of Multiple Deprivation (Smith, Noble, Noble, Wright, & McLennan, 2015), which provides a weighted score of deprivation within geographic areas with a population of approximately 1500 residents. Higher scores reflect greater deprivation (Smith, Noble, Noble, Wright, & McLennan, 2015).

Perceived current wealth. Perceived current wealth was assessed by asking participants to rate their agreement or disagreement with three statements (modified from Hill, Prokosch, DelPriore, Griskevicius, & Kramer, 2016); “I feel that I live in a relatively wealthy neighbourhood”, “I feel relatively wealthy compared to others”, and “I feel that I have enough money”, on a scale between 0 (*Strongly disagree*) and 100 (*Strongly agree*; $\alpha = 0.68$).

Procedure

All data were collected between 1 - 7pm on 29/08/2017 via Qualtrics. After providing informed consent, participants were instructed to rate their current hunger on a 0-100 scale with anchors *not*

hungry at all and *extremely hungry* (randomized amongst other mood questions: *Happy, Calm, Hungry, Thirsty, Excited*)².

Participants then completed the intended consumption task. On each screen, participants were presented with a food image (order randomized anew for each participant). The instruction “Imagine you are just about to have a snack. What percentage of this food portion would you consume?” was presented above each image (for an example, see Figure 1). Participants moved a point on a sliding scale between 0 and 100 (place markers increased in 10-point intervals). Participants could place the point anywhere on the scale. After participants had indicated their intended consumption for the eight snacks, they indicated the percentage of the portion they thought was an appropriate amount for an average adult to consume as a snack, again on the 0-100 scale.

Figure 1. The portion-size task, showing an example of a small portion of an energy-dense snack. The food image was presented in the middle of the screen. All snacks were presented on a standard-sized white plate. A standard-sized pen was placed next to the plate for scale. The question appeared above the food image and the scale (0-100) appeared beneath it.

² Inclusion of self-reported hunger as a covariate in the analyses did not alter the overall pattern of results presented (see Supplemental Materials). Therefore, the results of the analyses without hunger included are presented in the main text.

Next, participants completed a series of measures about the snacks presented in the task. To ensure that these measures were not influenced by portion size, participants were presented with text labels rather than images (“fries”, “crisps”, “minstrels”, “chocolate chip cookies”, “raw carrot sticks”, “cucumber”, “grapes”, “blueberries”). On 0-100 scales, they reported how much they liked each food (*Not at all* to *Very much*), how frequently they usually consume each food (*Never* to *Very often*)³, and how healthy they considered each food to be (*Not healthy at all* to *Very healthy*).

In the final section, participants completed the 30-item Barratt Impulsiveness Scale (Patton, Stanford, & Barratt, 1995; $\alpha = 0.83$)⁴ and a series of demographic measures, including age, height, and weight. In this section, participants also completed the measures of socioeconomic status (for details, see above). Finally, to assess awareness of the study hypotheses, participants were asked to report “What do you think we were expecting to find in this study?”⁵. Following completion of the study, participants were presented with an on-screen debrief sheet.

Analyses

All data processing and analyses were completed using R (R Development Core Team, 2014).

All data files and R scripts can be accessed on the Open Science Framework (https://osf.io/6438n/?view_only=c5a5b81c00544590948fc3f878456c49).

The percentage values for the intended consumption and appropriateness questions were converted to grams and calories. Grams were standardized to *z*-scores to allow for analyses of the

³ To check that perceived frequency matched absolute frequency of consumption, participants were also asked to report how often they consumed the food in the past month. For each food, participants selected one of eight responses (*Never in the past month*, *Once in the past month*, *2-3 times in the past month*, *Once per week*, *2-3 times per week*, *4-6 times per week*, *Once per day*, *More than once per day*). All levels of the objective frequency variable predicted subjective frequency in a standard linear regression model ($ps \leq 0.001$). Thus, the objective frequency variable was not analyzed further.

⁴ This study is part of a larger project that focuses on how socioeconomic status influences eating behavior. To inform future studies, a battery of additional measures was included which was designed to assess trait-eating behavior, plate clearing tendencies, self control, and time perspectives. A full list is included in the Supplemental Materials. These measures were not analyzed in relation to the hypotheses addressed here.

⁵ Two participants mentioned a link between portion size and income (P1: “what people conceive to be a normal sized food portion depending on their current income and their family's income as a child”; P2: “Portion sizes, diet, income”).

main effect of snack energy-density as the baseline weight of the low energy-dense snacks was greater than the baseline weight of the high energy-dense snacks (99 g vs. 65 g, respectively). Analyses of Variance were performed on intended consumption with portion size (small vs. large) and snack energy-density (low vs. high) as within-participants factors. Linear multilevel models were used to test for interacting effects of socioeconomic status and portion size on intended consumption using the lmerTest package in R (Kuznetsova et al., 2013). Separate multilevel models were computed for each measure of socioeconomic status. Predictors were scaled and mean-centered. Random slopes (and intercepts) were specified for the effect of portion size for each participant and food item. In line with the second hypothesis, the results for intended consumption of the energy-dense snacks are presented in the main text. The model outcomes with snack energy-density (low vs. high) included as an additional fixed-effect factor are presented in the Supplemental Material.

Bayes factors were also computed to determine support for the null or alternative hypotheses as frequentist analyses can only test whether a null hypothesis can be rejected. A Bayes factor less than 0.33 constitutes ‘moderate’ support for the null hypothesis whereas a Bayes factor of more than 3 constitutes ‘moderate’ support for the alternative hypothesis (for interpretations of Bayes factors, see Lee & Wagenmakers, 2013). Bayes factors were calculated using the BayesFactor package in R, using the default prior of 0.707 (Morey, Rouder, & Jamil, 2015).

Frequentist mediation analyses were conducted using the mediation package in R with nonparametric bootstrapping (samples: 10,000; Tingley, Yamamoto, Hirose, Keele, & Imai, 2014) and Bayesian mediation analyses using the BayesMed package (Nuijten, Wetzels, Matzke, Dolan, & Wagenmakers, 2014).

Results

The Effects of Portion Size and Snack Energy-Density on Intended Consumption

Participants intended to eat more from the large portion ($M = 1.43$; $SD = 1.08$) than from the small portion ($M = 0.56$; $SD = 0.53$), $F(1, 510) = 949.93$, $p < 0.001$, $gen. \eta^2 = 0.231^6$. This confirms the first hypothesis. Furthermore, and again as predicted, this portion-size effect was larger for the high energy-dense snacks ($M = 1.06$, $SD = 0.83$) than for the low energy-dense snacks ($M = 0.69$; $SD = 0.86$), as indicated by the reliable two-way interaction between portion size and snack energy-density, $F(1, 510) = 59.78$, $p < 0.001$, $gen. \eta^2 = 0.013$.

Converted to calories, participants intended to consume more calories from the large portions of the high energy-dense snacks ($M = 241$ kcals, $SD = 106$ kcals) than from the small portions ($M = 142$ kcals, $SD = 51$ kcals), $t(510) = 20.56$, $p < 0.001$, $g_{av} = 1.26$, $BF_{10} = 1.83e+65$. Similarly, calorie intake was greater from the large portions of the low energy-dense snacks ($M = 36$ kcals, $SD = 21$ kcals) compared with the small portions ($M = 23$ kcals, $SD = 10$ kcals), $t(510) = 13.67$, $p < 0.001$, $g_{av} = 0.84$, $BF_{10} = 1.32e+33$.

Taken together, these findings replicate previous work showing that, as predicted, intended consumption was greater from the large portions than from the small portions, especially for the high energy-dense snacks.

Socioeconomic Status as a Moderator of the Portion-Size Effect

Next, multilevel models were performed to test the central hypothesis that the portion-size effect for the high energy-dense snacks would be more pronounced amongst those with a lower socioeconomic status. Separate multilevel models were computed with highest educational level,

⁶ Note that participants intended to consume a lower percentage of the overall food portion presented from the large portion ($M = 60.90\%$, $SD = 29.20\%$) than from the small portion ($M = 74.44\%$; $SD = 28.21\%$), $F(1, 510) = 220.80$, $p < 0.001$, $gen. \eta^2 = 0.056$. Furthermore, participants intended to consume a lower percentage of the low energy-dense snacks ($M = 60.55\%$, $SD = 30.88\%$) than the energy-dense snacks ($M = 74.79\%$, $SD = 26.17\%$), $F(1, 510) = 123.67$, $p < 0.001$, $gen. \eta^2 = 0.062$. Thus, the percentage measure was sensitive to the portion-size and snack energy-density manipulations (i.e. participants did not simply select the same percentage across the small and large portions).

household income, neighborhood deprivation, and perceived current wealth as indicators of socioeconomic status.

Highest educational level. The portion-size effect was 21% larger for participants with low educational qualifications ($M = 1.19$) than for participants with high educational qualifications ($M = 0.94$; Figure 2)⁷, as indicated by a reliable two-way interaction between portion size and education ($p = 0.002$; Table 2). This supports the main study hypothesis. Converted from grams to calories, the portion-size effect was 110.67 kcals for participants with low educational qualifications, and 87.67 kcals for participants with high educational qualifications, reflecting a 21% difference in the portion-size effect on intended energy intake. Taken together, these analyses show that the portion-size effect on intended consumption of energy-dense snacks is moderated by education, such that lower education is associated with a larger portion-size effect for energy-dense food.

Household income. The portion-size effect was larger for participants with lower household incomes (1 SD below the mean: 1.17) than those with higher household incomes (1 SD above the mean: 0.96; Figure 2; Aiken & West, 1991)⁸, as indicated by a reliable two-way interaction between portion size and income ($p = 0.007$; Table 2). This represents an 18% increase in the portion-size effect. Converted into calories, the portion-size effect for participants with low household incomes (-1 SD) was 107.30 kcals and the portion-size effect for participants with high household incomes (+1 SD) was 91.11 kcals, representing a 15% difference in the portion-effect on intended energy intake. Thus, household income moderates the portion-size effect on intended consumption of energy-dense snacks, replicating the pattern of results observed for highest educational level.

Neighborhood deprivation. Although the numerical trend shows that the portion-size effect was larger for participants living in more deprived neighborhoods, the two-way interaction between

⁷ Note that difference between the small and large portion sizes was reliable for participants with low education, $t = 14.61$, $p < 0.001$, and for participants with high education, $t = 11.97$, $p < 0.001$.

⁸ Note that the portion-size effect was reliable at lower household incomes (- 1 SD), $t = 18.69$, $p < 0.001$, and at high household incomes (+ 1 SD), $t = 15.33$, $p < 0.001$.

portion size and neighborhood deprivation was not statistically significant ($p = 0.125$; Table 2; Figure 2). Note, however, that the three-way interaction between neighborhood deprivation, portion size, and snack energy-density was reliable (see Supplemental Material): the portion-size effect for the high energy-dense snacks was larger and the portion-size effect for the low energy-dense snacks was smaller for participants living in more deprived neighborhoods.

Perceived current wealth. The portion-size effect was larger for those with low perceived wealth (1 SD below the mean; $M = 1.21$) than those with high perceived wealth (1 SD above the mean; $M = 0.92$; Figure 2), representing a 24% difference⁹, as indicated by the reliable two-way interaction between portion size and perceived wealth ($p < 0.001$; Table 2). Converted to calories, the portion-size effect for participants with low perceived wealth (-1 SD) was 111.23 kcals and the portion-size effect for participants with high perceived wealth (+1 SD) was 87.14 kcals, reflecting a 22% increase portion-size effect with respect to energy intake. Combined, these analyses confirm that the effect of portion size on intended consumption of energy-dense food was moderated by perceived wealth, replicating the pattern of results observed for highest educational level, household income, and neighborhood deprivation.

The question of whether the moderating effect of perceived wealth was due to differences in actual wealth (i.e., household income) and, vice versa, whether the moderating effect of household income was due to differences in perceived wealth was also examined. Importantly, the moderating effects of household income and perceived wealth, respectively, remained significant when the other variable (perceived wealth and household income) was included as an additional fixed effect. These results are reported in detail in the Supplemental Materials.

Finally, the questions of whether the moderating effects of education, household income, and perceived current wealth were due to differences in weight status were addressed. When BMI

⁹ Note that the portion-size effect was reliable at low perceived current wealth (- 1 SD), $t = 18.79$, $p < 0.001$, and at high perceived current wealth (+ 1 SD), $t = 14.39$, $p < 0.001$.

was included as an additional fixed effect, the two-way interactions between these socioeconomic status indicators and portion size on intended consumption of the energy-dense snacks remained reliable. These results are also reported in the Supplemental Materials.

<i>Model</i>	<i>Estimate</i>	<i>SE</i>	<i>t</i>	<i>p</i>	Variance Explained	
					<i>R²_m</i>	<i>R²_c</i>
Model 1: Highest Educational Qualification (Baseline = Low)					0.261	0.655
(Intercept)	1.2785	0.0349	36.65	< 0.001		
Portion size	0.5323	0.0253	21.00	< 0.001		
Education	-0.0946	0.0296	-3.20	0.001		
Portion size by Education	-0.0610	0.0195	-3.13	0.002		
Model 2: Household Income					0.267	0.654
(Intercept)	1.2824	0.0346	37.10	< 0.001		
Portion size	0.5343	0.0245	21.80	< 0.001		
Income	-0.1209	0.0295	-4.09	< 0.001		
Portion size by Income	-0.0527	0.0196	-2.68	0.007		
Model 3: Neighborhood Deprivation					0.253	0.655
(Intercept)	1.2785	0.0351	36.40	< 0.001		
Portion size	0.5323	0.0256	20.81	< 0.001		
Neighborhood deprivation	0.0597	0.0298	2.01	0.046		
Portion size by Neighborhood deprivation	0.0302	0.0196	1.54	0.125		
Model 4: Perceived Current Wealth					0.268	0.655
(Intercept)	1.2785	0.0349	36.69	< 0.001		
Portion size	0.5323	0.0255	20.85	< 0.001		
Perceived current wealth	-0.1251	0.0294	-4.26	< 0.001		
Portion size by Perceived current wealth	-0.0706	0.0194	-3.63	< 0.001		

Table 2. Overview of the linear multilevel models conducted on intended consumption of the high energy-dense snacks. A separate model was computed for each SES indicator (highest educational level, household income, neighborhood deprivation, perceived current wealth). Portion size (small, large) and SES indicator were included as fixed effects. Estimate is the coefficient, *t* and *p* refer to the *t*-value and *p*-value for each fixed effect, respectively. *R²_m* is the variance explained by the fixed effects; *R²_c* is the variance explained by the fixed effects plus the random effects. *Note that *N* = 511 for all Models, except Model 2 (Household Income) where *N* = 504 due to exclusions (for details, see Footnote 1).

The Portion-Size Effect for Low Energy-Dense Food

Whilst participants with lower socioeconomic status displayed a larger portion-size effect for the high energy-dense snacks, the portion-size effect for the low energy-dense snacks did not change across levels of socioeconomic status. This is reflected in reliable three-way interactions between

(1) snack energy-density, portion size, and highest educational level; (2) snack energy-density, portion size, and household income; and (3) snack energy-density, portion size, and neighborhood deprivation ($ps \leq 0.029$). For more details, see the Supplemental Materials.

Figure 2. Intended consumption of energy-dense snacks as a function of portion size and socioeconomic status. Intended consumption values are predicted from separate multilevel models.

Mediation via Trait Impulsivity

Trait impulsivity partially mediated the effects of highest educational level ($p < 0.001$), household income ($p = 0.007$), and perceived current wealth ($p < 0.001$) on the portion-size effect for the high

energy-dense snacks. These findings are consistent with the third hypothesis. There was also a reliable mediating effect of trait impulsivity for the effect of neighborhood deprivation on the portion-size effect ($p = 0.004$) but the total effect and proportion mediated were not significant ($ps \geq 0.100$; Table 3). As shown in Figure 3, Bayesian mediation analyses revealed ‘extreme’ evidence for mediation via impulsivity for the effects of highest educational level ($BF = 23407.58$) and perceived current wealth on the portion-size effect ($BF = 23545.36$). There was also ‘moderate’ evidence for mediation via impulsivity for neighborhood deprivation ($BF = 3.92$) and ‘anecdotal’ evidence for mediation via impulsivity for household income ($BF = 2.75$). In sum, these findings suggest that increased consumption from large portions of energy-dense snacks amongst participants with lower socioeconomic status can be, in part, attributed to heightened trait impulsivity relative to participants with higher socioeconomic status.

	<i>Estimate</i>	<i>95% CI lower</i>	<i>95% CI upper</i>	<i>p</i>
Highest Educational Level (Baseline = Low)				
Indirect effect	-0.043	-0.069	-0.021	< 0.001
Direct effect	-0.079	-0.151	-0.007	0.031
Total effect	-0.122	-0.193	-0.052	< 0.001
Proportion mediated	0.351	-0.159	0.872	< 0.001
Household Income				
Indirect effect	-0.024	-0.045	-0.006	0.007
Direct effect	-0.082	-0.152	-0.011	0.023
Total effect	-0.106	-0.177	-0.035	0.004
Proportion mediated	0.222	0.061	0.687	0.011
Neighborhood Deprivation				
Indirect effect	0.026	0.008	0.049	0.004
Direct effect	0.034	-0.037	0.105	0.347
Total effect	0.060	-0.012	0.132	0.100
Proportion mediated	0.431	-1.639	3.226	0.103
Perceived Current Wealth				
Indirect effect	-0.002	-0.003	-0.001	< 0.001
Direct effect	-0.005	-0.008	-0.001	0.007
Total effect	-0.007	-0.010	-0.003	< 0.001
Proportion mediated	0.303	0.143	0.643	< 0.001

Table 3. Overview of the causal mediation analyses to examine the indirect effect of trait impulsivity. Separate mediation analyses were conducted for each of the SES indicators (highest educational level, household income, neighborhood deprivation, perceived current wealth) on the portion-size effect of the high energy-dense snacks.

Figure 3. Bayes Factors for each path within the mediation models to examine the mediating effect of trait impulsivity on the relationships between (a) highest educational level; (b) household income; (c) neighborhood deprivation; (d) perceived current wealth and the portion-size effect for the high energy-dense snacks. The mediation effect is represented by the overarching arrow. Note that Bayes Factors > 1 indicate evidence for the path (solid lines) whereas Bayes Factors < 1 indicate no evidence for the path (dotted lines).

Mediation via Appropriateness

The effects of highest educational level and household income on the portion-size effect for the high energy-dense snacks were partially mediated by perceptions of how much would be appropriate to eat from each portion (see Table 4). As shown in Figure 4, Bayesian analyses revealed ‘moderate’ and ‘anecdotal’ support for the indirect effect of appropriateness for highest educational level and household income, respectively. Furthermore, differences in appropriateness fully mediated the effect of neighbourhood deprivation on the portion-size effect (Table 4), but note that the total model and proportion mediated were not significant ($ps \geq 0.098$; Table 4). Bayesian analyses showed that the increased portion-size effect amongst those with lower perceived wealth was not

explained by differences in appropriateness (Figure 4). In sum, the increased portion-size effects amongst participants with lower educational qualifications and lower household incomes can be partially explained by increases in how much these participants considered appropriate to consume from the large portions.

	<i>Estimate</i>	<i>95% CI lower</i>	<i>95% CI upper</i>	<i>p</i>
Highest Educational Level (Baseline = Low)				
Indirect effect	-0.703	-0.121	-0.025	0.002
Direct effect	-0.177	-0.315	-0.043	0.012
Total effect	-0.248	-0.393	-0.108	< 0.001
Proportion mediated	0.284	0.109	0.652	0.003
Household Income				
Indirect effect	-0.029	-0.056	-0.005	0.014
Direct effect	-0.078	-0.145	-0.002	0.043
Total effect	-0.106	-0.177	-0.034	0.005
Proportion mediated	0.272	0.047	0.890	0.019
Neighborhood Deprivation				
Indirect effect	0.029	0.005	0.057	0.015
Direct effect	0.030	-0.038	0.096	0.370
Total effect	0.060	-0.012	0.130	0.098
Proportion mediated	0.490	-1.535	3.219	0.106
Perceived Current Wealth				
Indirect effect	-0.001	-0.002	0.001	0.310
Direct effect	-0.006	-0.009	-0.003	< 0.001
Total effect	-0.007	-0.010	-0.003	< 0.001
Proportion mediated	0.086	-0.105	0.261	0.310

Table 4. Overview of the causal mediation analyses to examine the indirect effect of appropriateness. Separate mediation analyses were conducted for each of the SES indicators on the portion-size effect for the high energy-dense snacks.

Figure 4. Bayes Factors for each path within the mediation models to examine the mediating effect of appropriateness on the relationships between (a) highest educational level; (b) household income; (c) neighborhood deprivation; (d) perceived current wealth and the portion-size effect for the high energy-dense snacks. The mediation effect is represented by the overarching arrow. Note that Bayes Factors > 1 indicate evidence for the path (solid lines) whereas Bayes Factors < 1 indicate no evidence for the path (dotted lines).

Manipulation and Data Quality Checks

As expected, participants rated the high energy-dense snacks as less healthy ($M = 11.89$, $SD = 15.23$) than the low energy-dense snacks ($M = 93.25$, $SD = 12.07$), $t(510) = 103.61$, $p < 0.001$, $g_{av} = 7.36$, $BF_{10} = 2.03 \times 10^{340}$, liked the high energy-dense snacks more ($M = 82.98$, $SD = 22.70$) than the low energy-dense snacks ($M = 62.06$, $SD = 33.33$), $t(510) = -17.61$, $p < 0.001$, $g_{av} = -1.13$, $BF_{10} = 1.17 \times 10^{51}$, and consumed the high energy-dense snacks more often ($M = 58.41$, $SD = 28.82$) than the low energy-dense snacks ($M = 47.80$, $SD = 32.95$), $t(510) = -8.18$, $p < 0.001$, $g_{av} = -0.51$, $BF_{10} =$

1.91+e+12. Thus, the manipulation of snack energy-density successfully elicited the expected differences with respect to these variables.

As shown in Table 5, intended consumption of the high energy-dense food was positively correlated with hunger ($r = 0.254, p < 0.001$), liking ($r = 0.579, p < 0.001$), trait impulsivity ($r = 0.258, p < 0.001$), and BMI ($r = 0.112, p = 0.013$). Thus, the intended consumption measure was influenced by factors known to influence actual eating behavior, suggesting it to be a valid proxy of actual consumption. The link between intended and actual consumption is further addressed in the Discussion.

The frequency of consuming the high energy-dense snacks was negatively correlated with household income ($r = -0.138, p = 0.002$; Table 5) and perceived current wealth ($r = -0.136, p = 0.002$; Table 5), and was positively correlated with neighborhood deprivation ($r = 0.115, p = 0.009$; Table 5). Furthermore, participants with lower educational attainment reported consuming the high energy-dense snacks more often ($M = 61.44, SD = 28.15$) than participants with higher education attainment ($M = 54.29, SD = 29.21; t = -2.95, p < 0.001$; Table 5). Thus, across all measures, participants with lower socioeconomic status reported consuming the energy-dense snacks more often than participants with higher socioeconomic status.

	<i>Mean (SD)</i>	<i>Variables</i>									
		Consumption - high energy- dense	Consumption - low energy- dense	Household income	Neighborhood deprivation	Perceived current wealth	Impulsivity	Liking - high energy- dense	Frequency - high energy- dense	Hunger	BMI
Consumption - high energy-dense	<i>M</i> = 46.94g (<i>SD</i> = 16.13)	-	-	-	-	-	-	-	-	-	-
Consumption - low energy-dense	<i>M</i> = 57.71g (<i>SD</i> = 25.47)	<i>r</i> = 0.258**	-	-	-	-	-	-	-	-	-
Household income	<i>M</i> = 35931.24 (<i>SD</i> = 25965.91)	<i>r</i> = -0.170**	<i>r</i> = -0.008	-	-	-	-	-	-	-	-
Neighborhood deprivation (range: 0.48-92.60)	<i>M</i> = 24.81 (<i>SD</i> = 16.47)	<i>r</i> = 0.068	<i>r</i> = -0.086	<i>r</i> = -0.229**	-	-	-	-	-	-	-
Perceived current wealth (range: 0-100)	<i>M</i> = 44.87 (<i>SD</i> = 21.49)	<i>r</i> = -0.169**	<i>r</i> = -0.006	<i>r</i> = 0.411**	<i>r</i> = -0.337**	-	-	-	-	-	-
Impulsivity (range: 30-120)	<i>M</i> = 62.46 (<i>SD</i> = 10.45)	<i>r</i> = 0.226**	<i>r</i> = 0.006	<i>r</i> = -0.120*	<i>r</i> = 0.125*	<i>r</i> = -0.227**	-	-	-	-	-
Liking - high energy-dense (range: 0-100)	<i>M</i> = 82.98 (<i>SD</i> = 16.29)	<i>r</i> = 0.579**	<i>r</i> = 0.039	<i>r</i> = -0.133*	<i>r</i> = 0.046	<i>r</i> = -0.114	<i>r</i> = 0.161**	-	-	-	-
Frequency - high energy-dense (range: 0 - 100)	<i>M</i> = 58.41 (<i>SD</i> = 20.41)	<i>r</i> = 0.391**	<i>r</i> = -0.025	<i>r</i> = -0.138*	<i>r</i> = 0.115*	<i>r</i> = -0.136*	<i>r</i> = 0.320**	<i>r</i> = 0.557**	-	-	-
Hunger (range: 0-100)	<i>M</i> = 37.81 (<i>SD</i> = 27.15)	<i>r</i> = 0.246**	<i>r</i> = 0.069	<i>r</i> = -0.062	<i>r</i> = 0.088	<i>r</i> = -0.122 *	<i>r</i> = 0.228**	<i>r</i> = 0.129*	<i>r</i> = 0.211**	-	-
BMI (kg/m²)	<i>M</i> = 27.49 (<i>SD</i> = 6.88)	<i>r</i> = 0.112	<i>r</i> = 0.025	<i>r</i> = -0.068	<i>r</i> = 0.131*	<i>r</i> = -0.164**	<i>r</i> = 0.118*	<i>r</i> = 0.013	<i>r</i> = -0.015	<i>r</i> = 0.017	-
	<i>N (%)</i>										
Education (low vs. high)	<i>N</i> _{low} = 294 (58%) <i>N</i> _{high} = 217 (42%)	<i>t</i> = -2.94*	<i>t</i> = 0.48	<i>t</i> = 7.66**	<i>t</i> = -4.17**	<i>t</i> = 6.26**	<i>t</i> = -5.22**	<i>t</i> = 2.22	<i>t</i> = 3.95**	<i>t</i> = -2.95*	<i>t</i> = -1.62

Table 5. The relationships between key study variables. *r* = the Pearson correlation coefficient; *t* = t-value. *N* = 511 for all measures, except household income where *N* = 504. ** *p* < 0.001, * *p* < 0.01

Discussion

This study examined some of the psychological mechanisms that translate unhealthy food environments into health inequalities. There was consistent evidence that people with lower socioeconomic status are more likely to overeat from large portions of energy-dense foods, which are highly salient and accessible in unhealthy food environments. The present results also show that this is driven by both increased impulsivity and increased perceptions of how much is appropriate to eat. These findings point to a significant double health burden of low socioeconomic status: those with a lower socioeconomic status are disproportionately exposed to unhealthy food environments, and specific psychological processes predispose them to overeat when exposed to those environments. These processes may play a key role for understanding the increased prevalence of obesity amongst those with lower socioeconomic status in many developed nations.

The portion-size effect on intended consumption was 18-24% larger for participants with lower educational attainment, household incomes, and perceived wealth. Converted to calorie intake, this was equivalent to a 15-22% increase in energy intake of up to 24 kcals for a single snacking occasion. Although this may not seem a large number, it has been shown that increases in body weight in England between 1999 and 2009 were equivalent to consumption of an additional 24 kcals per day during this period (Department of Health, 2011) indicating it to be sufficient to elicit health disparities in overweight. Consistent with previous work, the present study also found that participants with lower socioeconomic status reported consuming the energy-dense snacks more often than participants with higher socioeconomic status. Thus, not only do people with lower socioeconomic status tend to overeat from large portions of energy-dense snacks, they also eat them more often. Again, the combined effects of exposure and access to large portions of energy-dense food (e.g., Burgoine et al., 2016), higher number of consumption occasions of energy-dense snacks, and impulsivity and appropriateness perceptions that facilitate overeating, are likely to contribute the health inequalities in developed societies.

The finding that appropriateness perceptions predict the portion-size effect is consistent with previous work suggesting that the portion size serves as an “anchor” indicating how much is appropriate to eat, from which consumers often adjust incompletely (e.g., Marchiori et al., 2014). This finding is further in line with work showing that social norms have a strong effect on eating behavior more generally (Robinson, Thomas, Aveyard, & Higgs, 2014). Importantly, the present study also demonstrated that appropriateness perceptions mediated the effect of socioeconomic status on the portion-size effect, suggesting that those with lower socioeconomic status were more susceptible to overeat because they found it *appropriate* to eat a relatively larger percentage of the presented food. Perceptions could result from the exposure to unhealthy food environments, including easy access to large portions of energy-dense food and advertising of typically large portions of energy-dense food (e.g., Yancey et al., 2009). Thus, living in unhealthy food environments contributes to overeating through two mechanisms: not only are large portions more accessible but repeated exposure to excessive portions of energy-dense food could ‘normalize’ overconsumption when faced with these portions. Future research should examine other processes through which overconsumption from large portions of energy-dense food becomes more socially appropriate.

The increased portion-size effect displayed by participants with lower socioeconomic status was also mediated by differences in trait impulsivity. This suggests that those with lower socioeconomic status value the short-term reward of unhealthy food consumption more than those with higher socioeconomic status, increasing their susceptibility to overeat when faced with large portions of attractive food. To our knowledge, no previous work has addressed the role of impulsivity in responses to excessive food portions. Future research should examine this relationship and the underlying mechanisms in more detail. Viewing overconsumption from excessive portions as the result of impulsive processes also opens up new areas for interventions to tackle the portion-size effect by, for example, reducing the automaticity of continued eating (see

Cheema & Soman, 2008; Versluis & Papies, 2016b). This is particularly important since previous work has shown that information-based interventions targeting deliberative processes are largely ineffective and could widen diet-related health inequalities (e.g., Beauchamp, Backholer, Magliano, & Peeters, 2014).

Limitations and Future Research

A natural next step in this research area would be to replicate the current findings with actual consumption as an outcome measure. Importantly, intended consumption in this study positively correlated with factors known to predict actual eating, such as hunger and liking (e.g., Robinson et al., 2017). In line with previous work (e.g., Wilkinson et al., 2012), it is argued that the measure of intended consumption in the present study is likely to map well onto actual consumption. In addition, a recent meta-analysis demonstrated a larger effect of portion size on actual consumption ($d = 0.45$) than on intended consumption ($d = 0.18$; Zlatevska, Dubelaar, & Holden, 2014). This suggests that the present findings may actually underestimate the true effect of socioeconomic status on consumption from large portions. Nevertheless, this study did not assess factors that affect actual food intake, such as taste and satiety experiences. Thus, future studies should assess whether these additional factors modulate the effect of socioeconomic status on the portion-size effect.

The current study used a very conservative portion size manipulation, in which the small portion corresponded to a regular (i.e. recommended) serving and the large portion to a double serving (i.e. a 100% increase between the small and large portions). Both portions were selected to be both typical and feasible to consume as a snack. However, this could be seen as a subtle manipulation given that the median increase from the small to the large portion in the portion-size literature is 167% (Hollands et al., 2015). It is therefore likely that the effects of socioeconomic status would be even more pronounced with more extreme manipulations of portion size, which

may correspond well to ‘super-sized’ portions available in current food environments (Young & Nestle, 2012).

Obesity is a global public health crisis. This paper shows why this crisis particularly affects disadvantaged groups, and therefore critically informs the emerging psychology of health inequalities.

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