Children's portion-size effect for sugar-sweetened beverages and water in two field experiments: Moderating effects of liking and family socioeconomic status

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Abstract

Background: Childhood overweight and obesity are urgent health problems, especially among children from families with lower socioeconomic status. In the present study, we examined the contribution of large portions of sugar-sweetened beverages (SSBs) to excess calorie intake among children. While children have been shown to consume more food from large compared to small portions, this so-called ‘portion-size effect’ has not been systematically examined for beverages. Here, it was tested whether children consume more from larger compared to smaller portions of SSBs and water, and whether this portion-size effect is moderated by liking of the drink and family socioeconomic status. **Methods:** Two large-scale field experiments were conducted in which children ($N = 364$; 6-17 years) were offered a small (170 ml) or a large (275 ml) portion of a SSB or water to consume while they were completing a questionnaire. Liking of the drink and family socioeconomic status were also assessed. **Results:** Children showed a strong portion-size effect, consuming 55-56 ml more SSB and 37 ml more water from the larger portion. The portion-size effect was larger among children who liked the SSB or water. While the portion-size effect for the SSB was not moderated by family socioeconomic status, the “healthy” portion-size effect for water was stronger among children from families with higher socioeconomic status. **Conclusions:** Reducing the portion size of SSBs available to children could play a key role in curbing excess calorie intake. In the absence of other interventions, however, simply providing large portions of water may benefit especially the intake of children from more privileged backgrounds.

Keywords: health behavior, sugar-sweetened beverage, water, children, health inequalities, open data

Introduction

Overweight and obesity are urgent health problems among children. In England, for example, one third of 10-11-year-olds is overweight or obese (1). The prevalence of overweight and obesity is especially pronounced for children from more deprived families (1). The consumption of sugar-sweetened beverages (SSBs) has been shown to contribute to excess calorie intake and weight gain in children (2–5). Little is known, however, about the factors that affect children's consumption of SSBs. To address the obesity crisis among children, it is important to understand how environmental and psychological factors contribute to overconsumption of SSBs, and thus how excessive calorie intake can be reduced. The current paper examines whether the availability of excessive portions increase children's intake of SSBs, and whether this is affected by liking of the drink and family socioeconomic status.

In the domain of food, portion size is known to strongly affect intake. For children, consumption increases on average by 20% when the available portion doubles (see 6, for a meta-analysis). This so-called 'portion-size effect' is especially pronounced – and especially problematic – for high energy-dense foods (7). The present work systematically examined whether a similar portion-size effect exists for consumption of SSBs (Experiments 1 and 2). In addition, we examined whether a portion-size effect also occurs for water, a healthy alternative to SSBs (Experiment 2). It was further predicted that the portion-size effect would be especially pronounced when children like the drink. This would suggest that the availability of large beverage portions influences intake in interaction with personal preferences, thus offering further potential intervention targets.

Overweight is a particular problem among children from disadvantaged backgrounds. Thus, another aim of the present research was to examine the moderating effects of family socioeconomic status on SSB and water intake. Recently, we showed that adults with a lower socioeconomic status are more susceptible to the food portion-size effect, partly because

lower socioeconomic status was associated with finding larger portions more appropriate (8). Children from families with lower socioeconomic status consume more SSBs (9–11). This could suggest that these children find increased consumption from large portions more appropriate or ‘normal’ than more privileged children. The current research tested the hypothesis that the portion-size effect for SSBs is especially pronounced among children from families with a lower socioeconomic status. Examining the link between family socioeconomic status and the portion-size effect for sugary drinks would increase our understanding of the contributors to weight and health disparities in children.

In two field experiments, children were given a small or a large portion of a SSB (Experiments 1 and 2) or water (Experiment 2) to drink, and intake was assessed. Additional measures included liking of the drink (Experiments 1 and 2) and family socioeconomic status (Experiment 2). It was hypothesized that children would drink more from the large portion than from the small portion, especially if they like the drink more. In addition, it was predicted that the portion-size effect for the SSB would be especially pronounced among children from lower socioeconomic backgrounds.

Experiment 1

Method

Participants. 138 children who visited the Glasgow Science Centre with a parent or legal guardian participated in the experiment. We powered our study to detect a medium-sized effect of Cohen’s $d = 0.45$ based on a recent meta-analysis examining the effect of portion size on actual food consumption (6). An *a priori* power calculation using G*Power 3.1 (12) showed that with 80% power, $\alpha = 0.05$, $d = 0.45$, a minimum sample size of 124 ($N = 62$ per group) was required to detect an effect of portion size on consumption in a one-tailed independent-samples t-test. Fourteen children were excluded from the analyses because no

valid consumption data could be obtained ($N = 8$), they were served an incorrect amount by the experimenter (i.e., more than 10 ml more or less than the pre-determined amount; $N = 1$), or because they requested and received a refill of their drink ($N = 5$). As a result, 133 children were included in the analyses (5-17 years, mean age 9.38 years, $SD = 2.36$, 47 male, 77 female, 9 missing). The sample characteristics are presented in Table 1.

The experiment was approved by the research ethics committee at the Institute of Neuroscience and Psychology, University of Glasgow (application no. 300150176). Informed consent was obtained from participants' parent or legal guardian after the nature and possible consequences of the study were explained to the children and to their parent or legal guardian. Children could withdraw from the study at any time.

<i>Characteristic</i>	<i>Small portion</i>	<i>Large portion</i>
	<i>N</i>	<i>N</i>
Gender (9 missing)		
Female	42	35
Male	21	26
Self-reported liking of the beverage (3 missing)		
Low (disgusted face emoticon)	3	1
Medium (neutral face emoticon)	19	19
High (happy face emoticon)	45	43
Self-reported thirst (3 missing)		
Low ("Not thirsty at all")	12	6
Medium ("Quite thirsty")	40	47
High ("Very thirsty!")	15	10
	<i>M (SD)</i>	<i>M (SD)</i>
Age (years; 7 missing)	9.03 (2.29)	9.75 (2.39)

Table 1. Sample characteristics as a function of portion-size condition. *M* = mean; *SD* = standard deviation.

Design. The experiment had a two-factor between-participants design in which the children received either a small or a large portion of a sugar-sweetened beverage. The amount of the beverage consumed was measured in ml. Self-reported liking of the beverage was assessed and was included as an additional predictor to assess interactions with the effect of portion size on consumption. Self-reported thirst was included as a covariate. Age (in years) and gender were also included as covariates in separate models.

Materials.

Beverages. All beverages were a mixture of 1 part sugar-sweetened strawberry-flavored cordial (Ribena Strawberry, Lucozade Ribena Suntory Ltd.) and 5.5 parts water. Cups were filled to a comfortable drinking level, such that the small cup contained contained 170 ml of sugar-sweetened beverage and the large cup contained 275 ml.

Questionnaire. The paper-and-pencil questionnaire used was phrased in simple language and used 3-point scales with emoticons or simple text labels as response options to be accessible to the full age range of participants. The questionnaire is available via the Open Science Framework: https://osf.io/n42ez/?view_only=e6e3e5cb54a94685b8eb99fd5f9a1593. Before consumption, participants were asked to indicate their current levels of thirst by selecting one of three text labels (*Very thirsty*; *Quite thirsty*; *Not thirsty at all*). Whilst tasting the drink, participants indicated their liking of the drink and of the flavor of the drink again by selecting one of three emoticons (happy face, neutral face, disgusted face). They were then asked to describe the drink in 3 words, to rate its sweetness, saltiness, bitterness, and sourness, to indicate how often they drank it, to rate its healthiness, and to name their favorite drink. After indicating what they thought the experiment was investigating and again reporting their thirst, they reported their age and gender. With the help of their guardian, participants reported their weight and height. Obtaining reliable weight and height

information proved very difficult, however, with many parents or legal guardians knowing neither value, so that these data were not considered further.

Procedure. Children were invited to participate in a taste test and, if interested, their guardian received a study information sheet and provided informed consent for the child. The experimental procedure was then explained to both the child and the guardian. The participant was seated at a table and first received the questionnaire to answer the hunger and thirst questions before consumption. Then, the beverage was handed to the participant. Participants were asked to sample at least a bit. They were further told that they could drink as much or as little as they liked, and that there was more available if they would like to drink more. Participants then completed the questionnaire while sampling the beverage. Once the participant had completed the questionnaire, the questionnaire and the cup were removed, and any remaining beverage was weighed. The participant and their guardian were then fully debriefed. The awareness questions and debriefing revealed that no participant correctly guessed the aim of the study.

Analyses. All data processing and analyses were completed using R (13). All data files and R scripts can be accessed on the Open Science Framework (https://osf.io/n42ez/?view_only=e6e3e5cb54a94685b8eb99fd5f9a1593). A one-tailed Welch's independent-samples t-test was performed on the amount of beverage consumed (in ml) with portion size (small vs. large) as a between-participants factor (14). Hedge's *g* is the reported effect size measure (15).

Linear multiple regression analyses were then conducted to examine the moderating effect of liking on the portion-size effect. Very few children indicated low liking ($N = 4$, 3% of the sample) so we excluded these responses from the analyses. Liking was thus entered as a two-level categorical variable (neutral, high liking). Further multiple regression analyses were then conducted with thirst, gender, and age as covariates. Thirst and gender were

entered as 3- and 2-level categorical variables, respectively, and age was entered as a continuous variable. All predictors and covariates were scaled and mean-centered.

We also computed Bayes factors 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 16). Bayes factors were calculated using the BayesFactor package in R, using the default prior of 0.707 which corresponds to a medium-to-large effect (17).

Results

Children consumed 56 ml more of the sugar-sweetened beverage from the large portion than from the small portion, $t(104.8) = -4.11$, $p < 0.001$, $g = -0.72$, $BF_{10} = 373.35$. This effect can be seen in Figure 1. This supports the main study hypothesis and demonstrates a clear portion-size effect.

Figure 1: The average amount of SSB consumed from the small portion and from the large portion. In each box, the horizontal solid lines show the medians and the black diamonds show the means. The upper and lower “hinges” correspond to the first and third quartiles. The vertical lines at their respective end points capture the location of extreme values. There were no outliers (i.e. values exceeding the interquartile distance by more than 1.5).

As hypothesized, children displayed a portion-size effect when the drink was highly liked (82 ml) but not when liking of the drink was neutral (-3 ml). This was reflected in a reliable two-way interaction between portion-size and liking (Table 2).

Thirst and liking also had significant main effects on consumption, such that the amount consumed was greater when children felt thirsty or liked the sugar-sweetened beverage more ($p < 0.001$; Table 2, Models 1 and 2). Importantly, the effect of portion size on intake cannot be attributed to differences in thirst, age, or gender between the small and large

portion conditions: the effect of portion size remained when these variables were entered as covariates (Table 2, Models 2-4).

<i>Model</i>	<i>Standardised Coefficient</i>	<i>Unstandardised Coefficient</i>	<i>SE</i>	<i>t</i>	<i>p</i>	<i>R</i> ²
Model 1: Liking						0.307 ***
(Intercept)	0.00	147.37	6.22	23.70	< 0.001	
Portion size (Reference = Small)	0.34	28.40	6.24	4.55	< 0.001	
Liking (Reference = Medium)	0.37	30.31	6.24	4.85	< 0.001	
Portion size by Liking	0.24	19.76	6.27	3.15	0.002	
Model 2: Thirst (Covariate)						0.261 ***
(Intercept)	0.00	71.81	17.10	4.20	< 0.001	
Portion size (Reference = Small)	0.32	26.50	6.43	4.12	< 0.001	
Thirst						
Not thirsty	Reference	Reference	-	-	-	
Quite thirsty	0.45	78.89	18.85	4.19	< 0.001	
Very thirsty	0.50	104.37	22.29	4.68	< 0.001	
Model 3: Age (Covariate)						0.119 ***
(Intercept)	0.00	143.53	7.01	20.46	< 0.001	
Portion size (Reference = Small)	0.35	29.01	7.13	4.07	< 0.001	
Age	-0.04	-3.49	7.13	-0.49	0.630	
Model 4: Gender (Covariate)						0.141 ***
(Intercept)	0.00	144.27	6.98	20.67	< 0.001	
Portion size (Reference = Small)	0.32	26.91	7.04	3.82	< 0.001	
Gender (Reference = Female)	0.16	13.38	7.04	1.90	0.060	

Table 2. Overview of the linear regression models predicting the amount of sugar-sweetened beverage consumed. Separate models were conducted to test for the effects of liking, thirst, age, and gender. All model fits were reliable (*** $p < 0.001$).

Discussion

Experiment 1 shows clear evidence of a portion-size effect on children's consumption of a sugar-sweetened beverage. In line with our hypotheses, children consumed more SSB from a large portion than from a small portion. In addition, this portion-size effect occurred only when children liked the SSB. These findings suggest that exposure to large portions of SSBs could contribute to excessive calorie intake and weight gain in children.

Experiment 2

Experiment 2 was designed to extend the findings of Experiment 1 in two important ways. First, we examined whether exposure to a large portion of water increases children's intake (similar to large portions of the sugar-sweetened drink), thus producing a "healthy" portion-size effect. Second, we tested whether the portion-size effect for sugar-sweetened beverage would be especially pronounced amongst children from families with a lower socioeconomic status (as an established predictor of childhood overweight and obesity).

Method

Participants. 313 children who visited the Glasgow Science Centre with a parent or legal guardian participated in the experiment. An *a priori* power calculation using G*Power 3.1 (12) showed that with 80% power and $\alpha = 0.05$, and based on an anticipated medium effect of portion size on consumption ($d = 0.45$), a minimum sample size of 248 ($N = 62$ per group) was required to detect an effect of portion size for water and the SSB. A further power analysis revealed that 101 participants would be required within each cell (i.e. total $N = 404$) to detect a small-to-medium sized effects of family socioeconomic status on sugar-sweetened beverage consumption from the large portion ($f^2 = 0.08$, $\alpha = 0.05$, power = 0.80, number of predictors = 1).

Children were excluded from the analyses if they shared or spilt their drink ($N = 14$), they were served an incorrect amount by the experimenter ($N = 1$), they requested an alternative drink to that assigned before, during, or after completion ($N = 15$), they were instructed to consume less of the drink by a family member ($N = 3$), they had participated in Experiment 1 ($N = 1$), they were unable to drink from the cup provided ($N = 1$), they withdrew during completion of the questionnaire ($N = 1$), or because of an experimenter error ($N = 7$). As in Experiment 1, we also excluded children who requested and received a refill of

their drink ($N = 39$). In Experiment 2, children who had finished their drink were prompted by the experimenter whether they would like a refill, unlike in Experiment 1 where the children actively had to ask for a refill. This may have results in a higher number of children requesting and receiving a refill in Experiment 2 compared to Experiment 1. In total, 231 children were included in the analyses. The sample characteristics are reported in Table 3.

The experiment was approved by the research ethics committee at the Institute of Neuroscience and Psychology, University of Glasgow (application no. 300160161). Informed consent was obtained by a parent or legal guardian after the nature and possible consequences of the study were explained to the children and to their parent or legal guardian. Children could withdraw from the study at any time.

Design. The experiment had a 2 (portion size: small vs. large) $\times$ 2 (drink type: sugar-sweetened vs. water) between-participants design. Participants were randomly assigned to conditions, such that the design was fully counterbalanced after every 40 participants. The socioeconomic status of participants' parent or legal guardian was operationalized as a discrete categorical variable for highest educational level (low vs. high) and as continuous variables for household income, perceived wealth, and neighborhood deprivation. Self-reported liking of the beverage was included as a categorical predictor to assess the interaction with portion size on consumption, as in Experiment 1.

<i>Characteristic</i>	SSB		Water	
	<i>Small portion</i>	<i>Large portion</i>	<i>Small portion</i>	<i>Large portion</i>
	<i>N</i>	<i>N</i>	<i>N</i>	<i>N</i>
Gender (10 missing)				
Female	26	34	33	29
Male	23	25	22	29
Highest Educational Qualification (24 missing)				
Low Educational attainment (below undergraduate degree)	15	21	18	12
High Educational attainment (undergraduate degree or above)	31	34	36	40
Liking (4 missing)				
Low (disgusted face emoticon)	6	3	1	2
Medium (neutral face emoticon)	15	24	26	26
High (happy face emoticon)	27	35	29	33
Self-reported thirst (2 missing)				
Low ("Not thirsty at all")	6	9	18	12
Medium ("Quite thirsty")	35	42	31	43
High ("Very thirsty!")	7	12	8	6
	<i>M (SD)</i>	<i>M(SD)</i>	<i>M(SD)</i>	<i>M(SD)</i>
Age (years; 9 missing)	9.31 (2.35)	9.95 (2.79)	9.35 (2.73)	9.71 (2.70)
Pre-Tax Household Income (GBP; 60 missing)	71945 (85041)	56226 (35460)	63944 (43042)	70187 (49197)
Neighborhood Deprivation (SIMD score, 75 missing)	15.81 (11.54)	14.09 (8.77)	16.07 (12.07)	14.65 (10.92)
Perceived Wealth (1-5; 23 missing)	3.49 (0.82)	3.47 (0.74)	3.59 (0.79)	3.54 (0.80)

Table 3. Sample characteristics within each of the between-participants conditions, portion size and drink type. There were no reliable effects of condition on any of these sample characteristics ($ps \geq 0.287$).

Materials

Beverages. Participants were provided either with the same SSB as in Experiment 1 or with still, bottled water (Highland Spring Limited, UK). The portions were the same as in Experiment 1 (170 ml and 275 ml for the small and large portions, respectively).

Questionnaire. The paper-and-pencil questionnaire used was phrased in simple language, used 3-point scales, and presented emoticons or simple text labels as response options to be accessible to the full age range of participants. The questionnaire is available via the OSF: https://osf.io/n42ez/?view_only=e6e3e5cb54a94685b8eb99fd5f9a1593.

Unlike in Experiment 1, the questionnaire did not focus on the sensory properties of consuming the beverage, but asked questions about children's local area, to focus children less on the drink and make consumption incidental to the task (18). Participants were first asked to indicate their current levels of thirst and hunger on a three-point scale, embedded amongst other mood questions (happy, tired). Next, participants completed a series of filler items on their local area. These items were not analyzed further. Participants were then asked to indicate, again by selecting an image on a 3-point scale, their liking of the drink provided, how often they drank it, and how healthy they think this drink is. They were then asked to name their favorite drink. Finally, they provided some demographic information (age, gender, weight, height) and what they thought the experiment was investigating.

Measures of Family Socioeconomic Status. The parent or legal guardian of each participant was asked to complete four measures of socioeconomic status. The majority of guardians participated in an adult version of the portion-size study ($N = 116$), whereas the remainder ($N = 31$) completed a short questionnaire on their socioeconomic status. Level of education was measured using the question "What is your highest educational qualification?". Parents or guardians indicated whether they had no formal qualifications, completed

secondary school, sixth form college, or obtained an undergraduate degree, graduate degree, or a doctoral degree. A subset of guardians provided an educational qualification as a free-text response and so did not circle one of these options. Where possible, these qualifications were classified during the data analyses to fit within one of the categories. Parents or guardians with qualifications below undergraduate degree were categorized as ‘low educational attainment’ ($N = 66$); parents or guardians with an undergraduate degree or above were classed as ‘high educational attainment’ ($N = 141$).

Household income was assessed by asking legal guardians: “What is your annual pre-tax household income, including all earners in your household, to the nearest £10,000?”.

Area-level neighborhood deprivation was assessed by asking guardians to report their full household postcode. Each postcode was linked to a Scottish Index of Multiple Deprivation score.

Finally, to assess perceived current wealth, participants were asked to rate their agreement or disagreement with three statements: “I feel that I live in a relatively wealthy neighborhood”, “I feel relatively wealthy compared to others”, and “I feel that I have enough money”, on a scale between 1 (*Strongly disagree*) and 5 (*Strongly agree*). Responses to these items (Cronbach’s $\alpha = 0.68$) were averaged.

Analyses

Analyses were identical to Experiment 1. In addition, multiple regression analyses were conducted to test for the interacting effects of family socioeconomic status and portion size on the amount consumed. Separate analyses were conducted for each measure of family socioeconomic status (education, household income, perceived wealth, neighborhood deprivation), and for each drink type (sugar-sweetened beverage, water).

Results

The Effect of Portion Size on Consumption.

Children consumed 57 ml more of the sugar-sweetened beverage from the large than from the small portion, $t(102.3) = -3.61$, $p < 0.001$, $g = -0.64$, $BF = 31.62$ (Figure 2). This replicates the results of Experiment 1 and again demonstrates a clear portion-size effect.

Children consumed 44 ml more water from the large than from the small portion, $t(107.3) = -3.03$, $p = 0.002$, $g = 0.55$, $BF_{10} = 10.08$ (Figure 2). Thus, there was also a clear “healthy” portion-size effect for water.

Overall, children consumed 27 ml more of the sugar-sweetened beverage than of the water provided, $t(223.0) = 2.36$, $p = 0.019$, $g = -0.31$, $BF_{10} = 1.99$.

Figure 2: The average amount of sugary-sweetened beverage (SSB) and water consumed in the small portion and large portion conditions. In each box, the horizontal solid lines show the medians and the black diamonds show the means. The upper and lower “hinges” correspond to the first and third quartiles. The vertical lines at their respective end points capture the location of extreme values. There were no outliers (i.e. values exceeding the interquartile distance by more than 1.5).

As in Experiment 1, the portion-size effect for the sugar-sweetened beverage was larger among children who very much liked the SSB (84 ml) compared to those who were neutral about the SSB (13 ml; see Table 4, Model 1). Similarly, the portion-size effect on water consumption was larger when the water was liked more (76 ml) than when liking of the water was neutral (16 ml). These results are reflected in a reliable two-way interaction between portion-size and liking (Table 4, Model 1). In addition, separate analyses of sugar-sweetened beverage and water consumption confirmed that the two-way interaction between liking and portion size was reliable for both drink types (full details of these analyses are reported on the OSF page).

As in Experiment 1, liking and thirst each had a significant main effect on consumption (Table 4, Models 1-2). Importantly, the effects of portion size remained highly reliable (Table 4, Models 2-4) when thirst, age, and gender were entered as covariates.

<i>Model</i>	<i>Standardised Coefficient</i>	<i>Unstandardised Coefficient</i>	<i>SE</i>	<i>t</i>	<i>p</i>	<i>R</i> ²
Model 1: Liking						0.254 ***
(Intercept)	0.00	137.44	5.19	26.49	< 0.001	
Portion size (<i>Reference</i> = Small)	0.27	23.58	5.20	4.53	< 0.001	
Drink type (<i>Reference</i> = SSB)	-0.17	-14.41	5.20	-2.77	0.006	
Liking (<i>Reference</i> = Medium)	0.28	24.12	5.21	4.63	< 0.001	
Portion size by Drink type	-0.01	-0.50	5.22	-0.10	0.924	
Portion size by Liking	0.19	16.33	5.23	3.12	0.002	
Drink type by Liking	-0.16	-13.73	5.23	-2.63	0.009	
Portion size by Drink type by Liking	-0.02	1.37	5.25	-0.26	0.795	
Model 2: Thirst (Covariate)						0.120 ***
(Intercept)	0.00	116.38	12.68	9.18	< 0.001	
Portion size	0.27	24.11	5.56	4.33	< 0.001	
Drink type (<i>Reference</i> = SSB)	-0.13	-11.59	5.62	-2.06	0.040	
Portion size by Drink type	-0.03	-2.89	5.60	-0.52	0.606	
Thirst						
Not thirsty	<i>Reference</i>	<i>Reference</i>	-	-	-	
Quite thirsty	0.09	16.29	14.46	1.13	0.261	
Very thirsty	0.15	38.47	19.39	1.98	0.049	
Model 3: Age (Covariate)						0.129 ***
(Intercept)	0.00	132.99	5.59	23.77	< 0.001	
Portion size (<i>Reference</i> = Small)	0.30	26.57	5.63	4.72	< 0.001	
Drink type (<i>Reference</i> = SSB)	-0.15	-13.14	5.61	-2.34	0.020	
Portion size by Drink type	-0.03	-2.33	5.62	-0.41	0.679	
Age	0.09	7.78	5.63	1.38	0.169	
Model 4: Gender (Covariate)						0.129 ***
(Intercept)	0.00	132.77	5.62	23.64	< 0.001	
Portion size (<i>Reference</i> = Small)	0.30	26.80	5.64	4.75	< 0.001	
Drink type (<i>Reference</i> = SSB)	-0.15	-13.50	5.63	-2.40	0.017	
Portion size by Drink type	-0.04	-3.24	5.66	-0.57	0.567	
Gender (<i>Reference</i> = Female)	0.09	7.99	5.65	1.42	0.159	

Table 4. Results of the linear regression analyses conducted on the amount of beverage consumed. Separate models were conducted to test for the effects of liking, consumption frequency, thirst, age, and gender. All model fits were reliable (*** $p < 0.001$).

Family Socioeconomic Status as a Moderator of the Portion-Size Effect on SSB Consumption.

Next, we tested the hypothesis that the portion-size effect on sugar-sweetened beverage consumption would be more pronounced amongst children from families with a lower socioeconomic status. We conducted separate linear multiple regression analyses for each indicator of family socioeconomic status. Note, that our measures of family socioeconomic status were all reliably associated in the expected directions. There were reliable positive correlations between household income and perceived wealth ($r = 0.510, p < 0.001$) and reliable negative correlations between household income and neighborhood deprivation ($r = -0.341, p < 0.001$) and between perceived wealth and neighborhood deprivation ($r = -0.324, p < 0.001$). Similarly, participants with high educational attainment had a greater household income ($t = -4.63, p < 0.001$) and perceived wealth ($t = -6.09, p < 0.001$), and lower neighborhood deprivation ($t = 3.52, p = 0.001$).

Contrary to our hypothesis, there was no reliable evidence that the portion-size effect was larger for children from families with lower household incomes ($p = 0.080$), perceived wealth ($p = 0.871$), educational attainment ($p = 0.307$), or higher neighborhood deprivation ($p = 0.534$; see Table 6). Bayesian regression analyses revealed evidence for the null hypothesis of no relationships between each measure of socioeconomic status and consumption from the small portion ($BFs \leq 0.59$), except perceived wealth where the evidence was inconclusive ($BF = 1.02$). There was also no evidence for a relationship between consumption from the large portion and all measures of socioeconomic status ($BFs \leq 0.61$), except household income where there was ‘anecdotal’ evidence for a relationship ($BF = 1.95$). Note, however, that this relationship was in the opposite direction to that predicted: children with higher household incomes consumed numerically more sugar-sweetened beverage than children from families with lower household incomes.

In sum, there was no evidence to support our hypothesis that children from more deprived families would be more susceptible to overconsume from the large portion of sugar-sweetened beverage.

<i>Model</i>	<i>Standardised Coefficient</i>	<i>Unstandardised Coefficient</i>	<i>SE</i>	<i>t</i>	<i>p</i>	<i>R</i> ²
Model 1: Household Income						0.175 **
(Intercept)	0.00	139.47	9.98	13.98	< 0.001	
Portion size (<i>Reference</i> = Small)	0.34	32.92	10.04	3.28	0.002	
Income	0.16	17.25	11.70	1.48	0.144	
Portion size by Income	0.19	21.00	11.82	1.78	0.080	
Model 2: Perceived Current Wealth						0.092 *
(Intercept)	0.00	144.63	8.71	16.49	< 0.001	
Portion size (<i>Reference</i> = Small)	0.29	26.74	8.75	3.06	0.003	
Perceived Current Wealth	0.14	12.96	8.90	1.45	0.149	
Portion size by Perceived Current Wealth	-0.02	-1.45	8.88	0.08	0.871	
Model 3: Highest Educational Attainment						0.112 **
(Intercept)	0.00	143.38	8.75	16.39	< 0.001	
Portion size (<i>Reference</i> = Small)	0.28	25.68	8.78	2.92	0.004	
Education (<i>Reference</i> = Low)	-0.12	-10.32	8.53	-1.21	0.230	
Portion size by Education	-0.10	-8.81	8.58	-1.03	0.307	
Model 4: Neighborhood Deprivation						0.061
(Intercept)	0.00	133.13	11.16	11.93	< 0.001	
Portion size (<i>Reference</i> = Small)	0.23	21.56	11.20	1.92	0.058	
Neighborhood Deprivation	-0.05	-4.67	12.05	-0.39	0.699	
Portion size by Neighborhood Deprivation	0.07	7.56	12.10	0.62	0.534	

Table 6: Results of the linear regression models conducted on the amount of sugar-sweetened beverage consumed. Separate models were computed for each measure of family socioeconomic status (household income, perceived wealth, highest educational qualification, and neighborhood deprivation). Portion size (small, large) and SES indicator were included as predictors. *t* and *p* refer to the *t*-value and *p*-value for each predictor. *R*² is the variance explained by the model. Fits for Models 1-3 were reliable (* *p* < 0.05; ** *p* < 0.01).

Family Socioeconomic Status as a Moderator of the Portion-Size Effect on Water Consumption.

We performed the same analyses on water consumption, to explore whether the portion-size effect on water consumption was moderated by family socioeconomic status.

Children from families with high household incomes displayed a larger portion-size effect than children from families with lower household incomes. This effect can be seen in Figure 2, and is reflected in the reliable two-way interaction between portion size and household income (Table 7, $p < 0.001$, Model 1). When decomposing this interaction, we found that the portion-size effect was 119.26 ml at relatively high levels of family income, and -14.71 ml at relatively low levels of family income (1 SD above and 1 SD below the mean family income, respectively, 19). Bayesian regression analyses similarly revealed ‘very strong’ evidence that higher household income were associated with greater water consumption from the large portion ($BF = 55.11$), but not from the small portion ($BF = 0.60$).

We found a similar moderating effect of perceived family wealth. This effect can also be seen in Figure 2, and is reflected in the reliable two-way interaction between portion size and perceived wealth (Table 7, $p = 0.002$, Model 2). Children from families with a relatively high perceived wealth displayed a clear portion-size effect ($M = 87.27$ ml) whereas those from families with relatively low perceived wealth did not ($M = -6.89$ ml; again 1 SD above and 1 SD below the mean perceived wealth, respectively). Confirming these findings, and consistent with the results for household income, Bayesian analyses revealed ‘strong’ evidence that perceived family wealth was associated with greater water consumption from the large portion ($BF = 23.59$), but not from the small portion ($BF = 0.34$).

We also found a similar moderating effect of educational attainment (Figure 2). The two-way interaction between portion size and education was marginally significant (Table 7,

$p = 0.053$, Model 3) and shows that children from families with higher educational attainment had a larger portion-size effect ($M = 75.46$ ml) than children from families with lower educational attainment ($M = 14.69$ ml). However, Bayesian t-tests comparing children from families with lower versus children higher educational attainment revealed inconclusive evidence for a difference in water consumption from the small portion ($BF = 1.02$) and anecdotal evidence of no difference in consumption from the large portion ($BF = 0.54$). Consistent with the frequentist analyses, however, additional Bayesian analyses revealed very strong evidence for a portion-size effect amongst children from families with high educational attainment ($BF = 33.54$), but not amongst children from families with low educational attainment ($BF = 0.35$).

Neighborhood deprivation did not reliably moderate the portion-size effect on water consumption ($p = 0.349$, Table 7, Model 4) and Bayesian analyses revealed evidence for the null hypotheses of no relationship between neighborhood deprivation and water consumption from the small or large portion ($BFs \leq 0.47$). Therefore, neighborhood deprivation was not analysed further.

Thus, a consistent pattern of results emerged in which children from families with a higher income, perceived wealth, and educational attainment displayed a larger portion-size effect for water.

We also examined the question of whether the moderating effect of family 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. Importantly, the moderating effects of household income and perceived wealth, respectively, remained significant when the other variable (perceived wealth and household income, respectively) was included as a covariate. This suggests that both actual and

perceived material wealth within families increased children's portion size effect for water.

These results are reported in detail in the Supplemental Materials on the OSF:

https://osf.io/n42ez/?view_only=e6e3e5cb54a94685b8eb99fd5f9a1593.

Finally, we examined whether the moderating effects of household income, perceived wealth, and education were due to differences in liking of the water or differences in thirst.

When liking was included as a covariate, the two-way interactions between portion size all socioeconomic status indicators, except neighborhood deprivation, were reliable ($ps \leq 0.040$).

Similarly, when thirst was included as a covariate, the two-way interactions between portion size and all socioeconomic status indications, except neighborhood deprivation, were reliable ($ps \leq 0.047$). Full details of these analyses are reported on the OSF:

https://osf.io/n42ez/?view_only=e6e3e5cb54a94685b8eb99fd5f9a1593.

<i>Model</i>	<i>Standardised Coefficient</i>	<i>Unstandardised Coefficient</i>	<i>SE</i>	<i>t</i>	<i>p</i>	<i>R</i> ²
Model 1: Household Income						0.307 ***
(Intercept)	0.00	118.13	8.29	14.25	< 0.001	
Portion size	0.31	26.14	8.29	3.15	0.002	
Income	0.26	19.95	7.49	2.67	0.009	
Portion size by Income	0.40	29.90	7.46	4.01	< 0.001	
Model 2: Perceived Current Wealth						0.186 ***
(Intercept)	0.00	117.90	7.27	16.15	< 0.001	
Portion size	0.25	20.10	7.27	2.76	0.07	
Perceived Wealth	0.23	18.22	7.26	2.51	0.014	
Portion size by Perceived Wealth	0.29	23.31	7.24	3.22	0.002	
Model 3: Highest Educational Qualification						0.118 **
(Intercept)	0.00	118.32	7.70	15.37	< 0.001	
Portion size	0.28	22.54	7.70	2.93	0.004	
Education	0.01	1.24	8.04	0.15	0.878	
(Reference = Low)						
Portion size by Education	0.18	15.66	8.01	1.96	0.053	
Model 4: Neighborhood Deprivation						0.030
(Intercept)	0.00	110.91	9.40	11.80	< 0.001	
Portion size	0.11	8.72	9.43	0.92	0.359	
Neighborhood Deprivation	0.10	7.03	9.01	0.78	0.438	
Portion size by Neighborhood Deprivation	0.12	8.54	9.04	0.94	0.349	

Table 7: Results of the linear regression models conducted on the amount of water consumed. Separate models were computed for each measure of family socioeconomic status (household income, perceived wealth, highest educational qualification, and neighborhood deprivation). Fits for Models 1-3 were reliable (** $p < 0.01$; *** $p < 0.001$).

Figure 3: The amount of water consumed as a function of portion size and socioeconomic status. Consumption values are predicted from separate linear regression models.

Discussion

The results of two experiments provide clear and consistent evidence that children drink more from larger than from smaller beverage portions. In both experiments, children consumed significantly more from the larger portion than from the smaller portion of a sugar-sweetened beverage (56 ml and 57 more in Experiments 1 and 2, respectively). In Experiment 2, we also

examined the portion-size effect on children's water consumption. We found that children similarly drank more from the larger portion than from the smaller portion of water (44ml). Thus, there was a "healthy" portion-size effect for water consumption, albeit numerically smaller than the portion-size effect for sugar-sweetened beverage consumption. To our knowledge, these experiments are the first to directly test the effect of portion size on children's beverage intake outside a meal or snack context. Our results demonstrate that the availability of large portions of sugar-sweetened beverages can easily increase excess sugar and calorie intake among children and, via the same mechanisms, offering large portions of water can similarly enhance healthier beverage intake.

Socioeconomic status is a strong predictor of weight and health outcomes for adults and children alike. In the present study, we also tested whether children from families with a lower socioeconomic status would display a stronger portion-size effect for sugar-sweetened beverages. We reasoned that this might explain, in part, why children from lower socioeconomic backgrounds are more likely to consume excess calories and, in turn, be overweight or obese. We did not find evidence to support this hypothesis. However, our sample size was smaller than was required to detect the anticipated small-to-medium sized effect of socioeconomic status, which may account for the absence of a reliable effect in the frequentist analysis. Nevertheless, we also computed Bayes factors which measure evidence for the null and alternative hypotheses at a given sample size. Consistent with the frequentist statistics, the Bayesian analyses revealed support for the null hypothesis, suggesting that family socioeconomic status did not moderate the effect of portion size on children's sugar-sweetened beverage consumption. Future research should seek to replicate this finding. Furthermore, since our sample had a relatively high household income, we suggest that future research obtains a more representative sample of children across the socioeconomic spectrum.

Analyses of water consumption revealed consistent evidence that children from families with a higher socioeconomic status had a stronger portion-size effect for water, consuming relatively more from a larger than from a smaller portion of water than children from families with a lower socioeconomic status. These results were supported by Bayesian analyses. Furthermore, these results were not due to those children liking water more, or increased thirst. Thus, our results indicate that providing larger portions of water could be an effective way to increase healthy beverage consumption, especially amongst children from more privileged families.

Future research should examine why the portion-size effect for water is stronger among children from more privileged families. The finding that portion sizes of beverages affect children's intake, even when they don't finish the beverage provided, suggests that normative cues affect children's consumption behavior. One possibility is that children from more privileged families drink water more often, or drink it from larger portions, so that they find consuming larger amounts of water more normal. If this was the case, exposing children to large portions of water in settings outside of the home (e.g. in schools, after-school clubs), would not only increase their momentary water intake but would also normalize increased water consumption, thus helping to sustain healthier consumption across time. Future research should investigate how longer-term exposure to large portions of water could be harnessed to normalize water consumption and boost healthy beverage consumption.

Conclusion

The present study shows that children consume more water and sugar-sweetened beverage from large portions. The effect of portion size was especially pronounced if children liked the beverage provided. Thus, for children's beverage consumption, it matters not only which drink they are offered, but also in what size it is offered. Our findings suggest that in cases

where fully replacing sugar-sweetened beverages with water is not feasible, reducing the portion sizes of sugar-sweetened beverages offered to children could provide an effective way to curb excess calorie and sugar intake. By the same logic, increasing the size of available water portions could be an effective way to normalize and encourage healthy beverage consumption.

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Declarations

Ethics approval and consent to participate: Both experiments were approved by the research ethics committee at the Institute of Neuroscience and Psychology, University of Glasgow (Experiment 1 application no.: 300150176; Experiment 2 application no.: 300160161). Informed consent was obtained from participants' parent or legal guardian after the nature and possible consequences of the study were explained to the children and to their parent or legal guardian. Children could withdraw from the study at any time.

Consent for publication: All authors approved submission of the manuscript. All data is anonymized and there are no details, images, or videos relating to individual participants.

Availability of data and material: The datasets supporting the conclusions of this article are available in the Open Science Framework:

https://osf.io/n42ez/?view_only=e6e3e5cb54a94685b8eb99fd5f9a1593.

Competing interests: The authors declare that they have no competing interests.

Author contributions: K.M., R. R., and E. K. P. developed the study procedure for Experiment 1 and K. M. and R. R. collected the data. M. B. performed the data analyses. M. B. and E. K. P. further developed the study procedure for Experiment 2. M. B. coordinated data collection for Experiment 2 and performed the data analyses. M. B. and E. K. P. interpreted the data and wrote the manuscript. All authors approved submission.

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