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Associations between attitudes towards and reported intakes of sugars, low/no-calorie sweeteners, and sweet-tasting foods in a UK sample

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ABSTRACT

Public health initiatives are currently aiming to lower free sugar intakes for health benefits, but attitudes towards sugars, their alternatives such as low/no-calorie sweeteners (LNCS), and towards sweet-tasting foods may be hampering efforts. This work investigated associations between attitudes towards and the reported intakes of sugars, LNCS and sweet-tasting foods, and identified latent attitude profiles in subpopulations of adults in the United Kingdom. A total of 581 adults completed a questionnaire assessing their usual intake of sugars, LNCS and sweet-tasting foods, attitudes towards these foods and various demographic characteristics. Six principal components explained 39.1% of the variance in the attitude responses, named: 'Personal Impact', 'Personal Management', 'Apathy', 'Negativity', 'Perceived Understanding' and 'Perceived Nonautonomy'. Personal Impact was negatively associated with reported consumption of sugar-food and sweet-tasting food groups more frequently (smallest $\beta = -0.24$, $p < .01$). Personal Management was positively associated with reporting adding sugar and consuming sugar-food and sweet-tasting food groups more frequently (smallest $\beta = 0.14$, $p < .01$). Three latent classes of participants with distinct patterns of attitudes were identified, labelled: 'Feeling Ill-equipped' (n = 52), 'Actively Engaged' (n = 162) or 'Unopinionated' (n = 367). Individuals who were classed as Actively Engaged reported adding LNCS more frequently than those classed as Feeling Ill-equipped ($t(212) = -2.14$, $p < .01$), who reported consuming sweet-tasting food groups more frequently than those classed as Unopinionated ($t(417) = 2.65$, $p < .01$). These findings suggest the need for personalised approaches within public health initiatives, to reduce free sugar intakes.

1. Introduction

A high dietary intake of free sugars, defined as '*monosaccharides and disaccharides added to foods and beverages by the manufacturer, cook or consumer, and the sugars naturally present in honey, syrups, fruit juices and fruit juice concentrate, [but not those naturally present in intact fruit and vegetables or milk and dairy products]*' (World Health Organisation, 2015, p. 1.), has been associated with increased risk of a number of chronic health conditions, including dental caries, cardiovascular disease, type 2 diabetes, overweight and obesity, and some cancers (Huang et al., 2023; Lean & Te Morenga, 2016; Te Morenga, Mallard, & Mann, 2013, 2014; World Health Organisation, 2015). In response, public health initiatives have been aiming to lower the consumption of sugar-sweetened food and drink products, and of sweet taste in general (Pan American Health Organisation, 2016; Public Health England, 2018; Tedstone, Targett, & Allen, 2015; World Health Organisation, 2015). In parallel, products are being reformulated to maintain sweetness by switching to alternative sources of sweet taste, such as low- and no-calorie sweeteners (LNCS) (Pell et al., 2021; Scarborough et al., 2020).

Public support for such sugar-lowering strategies, however, is mixed (Hagmann, Siegrist, & Hartmann, 2018; Pell et al., 2019; Prada, Saraiva, Garrido, Rodrigues, & Lopes, 2020; Swift et al., 2018; Tang, Mars, James, De Graaf, & Appleton, 2021). Innate preferences for sugars and sweet tastes in humans are well recognised (Beauchamp, 2016), and consumers report many positive perceptions of sugars or sugar-sweetened foods and beverages (SSBs), to include experiences of

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pleasure (Fadupin, Ogunkunle, & Gabriel, 2015; Forde & Solomon-Moore, 2019; Gupta, Smithers, Harford, Merlin, & Braunack-Mayer, 2018; Morel et al., 2019; Palmedo & Gordon, 2019; Pielak, Czarniecka-Skubina, Trafiałek, & Głuchowski, 2019; Tang et al., 2021), the provision of energy (Tang et al., 2021), and some perceived health benefits (Hennessy, Bleakley, Piotrowski, Mallya, & Jordan, 2015; Ortega-Avila, Papadaki, & Jago, 2019; Zytnick, Park, Onufrak, Kingsley, & Sherry, 2015). Other positive perceptions of sugars relate to habits (Forde & Solomon-Moore, 2019; Morel et al., 2019; Ortega-Avila et al., 2019; Palmedo & Gordon, 2019; Pielak et al., 2019; Tang et al., 2021), familial, social and cultural norms (Fadupin et al., 2015; Morel et al., 2019; Palmedo & Gordon, 2019; Ortega-Avila et al., 2019; Tang et al., 2021), and a lack of knowledge of the health implications (Fadupin et al., 2015; Forde & Solomon-Moore, 2019; Hennessy et al., 2015; Palmedo & Gordon, 2019; Ortega-Avila et al., 2019; Tang et al., 2021). Many of these positive perceptions towards sugars also exist towards LNCS and sugar-free alternatives, such as 'diet' products (Forde & Solomon-Moore, 2019; Morel et al., 2019; Ortega-Avila et al., 2019; Palmedo & Gordon, 2019; Tang et al., 2021), and have been found for sweet-tasting foods regardless of the source of the sweet taste (Tang et al., 2021).

Whether these perceptions influence intakes of sweet taste, however, is unclear. Studies suggest some associations, predominantly in relation to sugar, but findings are inconsistent. For example, among female caregivers in America, the perception of SSBs as being healthy was associated with higher intakes (Hennessy et al., 2015). In a sample of Nigerian university students, positive attitudes towards SSBs were associated with greater intakes, despite awareness of the health implications (Fadupin et al., 2015). In Polish adults, sugar intakes were highest in persons who also had poorer knowledge of and expressed greatest concerns over sugar alternatives (Pielak et al., 2019). In a review on sugar consumption, Gupta et al. (2018) suggest only weak associations between attitudes towards sugars, knowledge of the health implications of consumption and intakes, while for SSBs, Calabro, Kemps, and Prichard (2023) report strong associations between SSB consumption and attitudes, intentions, habits, and social norms in their review and meta-analyses.

Associations with personal characteristics are also inconsistent. Attitudes, intakes and associations between attitudes and intakes of sugar-sweetened foods and beverages have been reported to differ with gender, age, ethnicity and education (Boles, Adams, Gredler, & Manhas, 2014; Gase, Robles, Barragan, & Kuo, 2014; Katou, Mori, & Ikawa, 2005; Pielak et al., 2019; Zytnick et al., 2015), but inconsistent findings from different studies make overall patterns unclear.

Attempts to modify free sugar intakes may benefit from greater elucidation and understanding of the associations between attitudes and intakes of sugars, LNCS and sweet-tasting foods. Others have also noted the value of recognising attitudes for both understanding intakes (Calabro et al., 2023; Gupta et al., 2018) and in attempting to change intakes (Hagmann et al., 2018; Pell et al., 2019; Prada et al., 2020), but these studies have focussed on sugars or sugar-sweetened products alone. Thus, the present study aimed to 1) examine the relationships between specific attitudes and intakes of sugars, LNCS and sweet-tasting foods; and 2) identify attitude profiles towards these food groups, together with individual characteristics. The study stemmed from an earlier qualitative study (Tang et al., 2021), where many varied attitudes towards sugars, LNCS and sweet-tasting foods were given by a variety of individuals, but where firm conclusions on the attitudes that are important for intakes or for changing intakes could not be ascertained. We hypothesized that relationships between attitudes and reported intakes, and attitude profiles would be found. The hypotheses were specified before the data were collected.

2. Methods

2.1. Participants

Six hundred adults were recruited via databases of interested persons, social media sites, the Prolific research participation platform and Bournemouth University's Psychology student research participation platform. Exclusion criteria were younger than 18 years of age and living less than one year in the UK. The study was granted ethical approval by the Research Ethics Committee of Bournemouth University (ID: 32878) prior to commencement and was run in accordance with the ethical guidelines of the British Psychological Association and the Declaration of Helsinki. All participants provided informed consent prior to participation.

2.2. Intake frequency estimates

Usual consumption of sugars, LNCS and sweet-tasting foods were estimated by asking participants for frequency of consumption of food

Table 1
Foods and food groups for which intake frequency estimates were requested.

Foods	
Adding sugar to coffee, tea and homecooked dishes	
Adding honey to coffee, tea and homecooked dishes	
Adding sweeteners to coffee, tea and homecooked dishes	
Sweet-tasting food groups	
Sugar-food groups	
Foods	**Examples**
Biscuits	cereal bars, toaster pastries (Pop Tarts), gluten free biscuits
Breakfast Cereal	ready to eat cereals, granola, muesli, porridge oats
Cakes & Morning Goods	cake bars and slices, American muffins, flapjacks, Swiss rolls, croissants, crumpets, English muffins, pancakes, buns, teacakes, scones, waffles, Danish pastries, fruit loaves, bagels
Chocolate & Sweet Confectionery 'not sugar-free or diet'	chocolate bars, filled bars, assortments, seasonal chocolate, all sweets except sugar-free sweets/ chewing gum
Ice Cream, Lollies & Sorbets 'not sugar-free or diet'	dairy and non-dairy, choc ices, arctic roll
Puddings	canned, chilled, frozen puddings
Sweet Spreads & Sauces 'not sugar-free or diet'	confectionery branded chocolate spreads, peanut butter, flavoured peanut butter, almond butter, cashew butter, coulis, compotes, cream-based toppings, brandy sauce
Yoghurts 'not sugar-free or diet'	sugar-sweetened dairy yogurt, fromage frais products, soya, goat sheep products, except natural yogurt and unsweetened yogurt or fromage frais
Fruit juice & Smoothies	unsweetened fresh fruit juice, fruit concentrate, unsweetened smoothies
Non-alcoholic fizzy drinks/pop 'not sugar-free or diet'	coke, Lucozade
Sugar-free food groups	
Foods	**Examples**
Chocolate & Sweet Confectionery 'sugar-free or diet'	sugar-free chocolate bars, filled bars, assortments, seasonal chocolate, all sweets, all sugar-free sweets/chewing gum
Ice Cream, Lollies & Sorbets 'sugar-free or diet'	dairy and non-dairy, choc ices, arctic roll
Yoghurts 'sugar-free or diet'	sugar-sweetened dairy yogurt, fromage frais products, soya, goat sheep products, except natural yogurt and unsweetened yogurt or fromage frais
Non-alcoholic fizzy drinks/pop 'sugar-free or diet'	coke, Lucozade

groups that have previously been identified to contribute most to free sugar intakes in the UK National Diet and Nutrition Survey from years 2012–2014 (Tedstone et al., 2015). Consumption of all sugar-food groups was requested. To allow consideration of the consumption of LNCS-sweetened foods and beverages, 'Chocolate and Sweet Confectionery', 'Ice Cream, Lollies and Sorbets', 'Yogurt' and 'Soft Drinks' were split into separate questions on 'not sugar-free or diet' and 'sugar-free or diet', to also create a 'sugar-free food groups' category. 'Sugar-food groups' and 'sugar-free food groups' were also combined to create a 'sweet-tasting food groups' category. All foods are provided in Table 1. Response options for all intake questions were: 'Rarely or never', 'Less than once a week', 'Once a week', '2–3 times a week', '4–6 times a week', '1–2 times a day', '3–4 times a day', and '5+ a day'.

2.3. Attitudes

Attitudes towards sugars, LNCS and sweet-tasting foods, were assessed where participants were asked to specify their level of agreement or disagreement with 81 statements referring to various aspects of these foods and their consumption. These statements were derived to reflect the themes gained from the earlier qualitative study (Tang et al., 2021). In this earlier study, seven focus groups, two dyadic and one solo interview were undertaken and transcripts analysed using inductive thematic analysis. Six themes were derived directly from the data: 'Value', 'Angle', 'Personal Relevance', 'Personal Responsibility', 'Understanding' and 'It's Not Up to Me'. Definitions of these themes and example quotes from each are provided in Table 2. The statements developed to reflect each theme are given in the Supplementary Materials, with those found to be important in this study also provided as part of our results. Because the themes were derived inductively from our qualitative data, no theoretical framework was applied. Consideration of themes without restriction by theory is considered one of the advantages of inductive analyses (Braun & Clarke, 2013; Thomas, 2006), and was used here to allow the elucidation of attitudes that may have been unforeseen in advance (Thomas, 2006). All statements were applied equally to sugar, LNCS and sweet-tasting food consumption, excepting where this was not appropriate, e.g., statements 'The current recommendations on sugar intake are realistic', and 'I am able to state the recommended intake of sugars' were applicable only to sugar consumption. Twenty-nine statements were relevant to sugars, 26 statements to LNCS, 23 statements to sweet-tasting foods, and four statements included both sugars and LNCS. Statements were written in the active voice and referred directly to the respondent, for example, 'I feel guilty whenever I consume sweet foods'. Statements were both positively and negatively worded and presented randomly across all themes, first in relation to sugars, second in relation to LNCS, and third in relation to sweet-tasting foods. At the start of the questionnaire, the terms 'sugar', 'sugars', 'sweeteners' and 'sweet foods' were defined as follows: 'The term 'sugar' refers to "regular" table sugar, i.e. sucrose. This may take the form of sugar grain/crystal, sugar cube, sugar sachet or sugar stick'; 'The term 'sugar**S**' refers to both 'sugar' and the sugars present in honey, syrups, unsweetened fruit juices and fruit juice concentrates. This excludes sugar from intact fruits and vegetables'; 'The term 'sweeteners' refers to low or no calorie sweeteners (LNCS) that are used in place of sugar in many foods and drinks as a reduced or no calorie alternative. For example, sucralose used in Splenda, stevia leaf extract used in Truvia, aspartame used in Canderel, etc. This excludes honey and syrups'; 'The term 'sweet foods' refers to all sweet-tasting foods, including fruits, sweet biscuits, cereals, spreads, confectionery, pastries, ice-cream etc, regardless of whether these are sweetened naturally, sweetened with sugar or sweetened with sweeteners'. Participants responded to all statements on a 5-point Likert scale from 'Strongly Disagree' to 'Strongly Agree'. The questionnaire was piloted among 13 volunteers and changes were made to improve comprehension and flow, prior to use in the study.

2.4. Demographic and lifestyle characteristics

Demographic characteristics assessed were: gender, age, ethnicity, highest education qualification level attained, and socio-economic classification (SEC) based on employment (Office for National Statistics, 2019; UK Government, 2020). Lifestyle characteristics assessed

Table 2
Themes identified in the qualitative study (Tang et al., 2021), definitions and example quotes.

Theme	Definition	Example Quotes
Value	What sugar, sweeteners and sweet-tasting foods can provide	"Let's say we're not gonna have cake any more because you can't make cake without either sugars or sweeteners alright so, if we get rid of both those things there's no more cake. To me, th-the life is too short, to do away with, good things in life." (DI1, P2) "Yeah like I don't really mind, I would rather be a bit curvy and happy and enjoy what I eat rather than obsessively worry all the time and restrict myself of things that I want." (FG6, P1)
Angle	Negativity surrounding sugar, sweeteners and sweet-tasting foods.	"To me, eating sweet things, is just, quite normal! Um I–I don't necessarily look upon it as a treat. It's like I fancy something sweet, I'm gonna have that." (FG3, P2) "The reason I don't pick diet is because I heard about aspartame and I've heard people get tumours. It might be a myth thing but both options are bad and it's better to do better the devil I know than I don't." (FG4, P1)
Personal Relevance	To be concerned personally and/or to change one's own behaviour	"Although there are a notable amount of people now who are kinda you know driving the healthy lifestyle, there is still a lot of people who are, you know, probably more in line with where I am, and slightly beyond, which is like pfftttt! Yeah, if you make it easy for me, maybe, but I've got other fish I need to fry right now and I'm not gonna get there." (DI1, P2)
Personal Responsibility	One has an active relationship with sugar, sweeteners and sweet-tasting foods	"I'll just go 'oh okay, that meal is mostly red for sugar [on the traffic light rating system] so I'll make sure the other meals are not red in other areas' so I make sure it's like lower, a different colour for anything else I buy, and that they don't add up. I could be buying four [. . .] things in the red zone and be like 'oh yeah that's fine cause I've had like seven things in the orange or green'." (FG4, P1)
Understanding	Acquiring, comprehending and applying insights on sugar, sweeteners and sweet-tasting foods.	"I think a lot has been done to educate people on sugar, but there seems to be no education on sweeteners and what they are." (FG7, P4) "I think my concern would be if people, mis-interpreted the message that said sweeteners are okay, and sugars are less okay. People might think, well I won't bother exercising nowand they think then if if I just turn to sweeteners." (FG3, P1)
It Is Not Up to Me	One takes a passive approach towards sugar, sweeteners and sweet-tasting foods, because intake is subject to other factors.	"I think people need professional help! You know for sugar? Cause of the fact that I've, I-y-yeah. I think she's right. It is a drug (pause) and when I when I need, I need it." (FG2, P6) "I think it's sneaky how much they put in stuff, it can be hard to stick to your plan or keep things in moderation when companies load things with sugar and fat." (FG6, P3)

were Body Mass Index (BMI) based on self-reported height and body weight, self-reported presence of any health condition that may influence eating and food choice, adherence to any diet, and food intolerances or allergies.

2.5. Questionnaire administration

The final questionnaire included the above sections in the order: (1) estimated intake frequencies, (2) attitudes, and (3) demographic and lifestyle questions. Additionally, two logical statements were included in the questionnaire to improve scale validity and identify careless responding (Abbey & Meloy, 2017; Kung, Kwok, & Brown, 2018). The two statements were: 1) 'All sugar is dug out from sugar mines at least 50 m deep'; 2) 'All sugar comes from the sea'. These statements were presented with the other attitude statements in a randomised order. Any respondent that agreed or strongly agreed with either statement was removed from analysis. The full questionnaire can be referred to in the Supplementary Materials. It was administered online, including the process of consent.

2.6. Data analysis

Responses to all intake frequency questions were converted into 'times per day' by taking the median of each category and dividing by seven for all responses provided per week, using 0 for the 'Rarely or never' category, and 5 for the '5+' category. Responses to attitude statements were coded from −2 to +2, with higher scores reflecting greater agreement. Negative statements were reverse scored. Completed questionnaires where participants had agreed or strongly agreed with either logical statement or where participants had chosen the option "neither agree nor disagree" for over 50% of the statements were then removed from all subsequent analyses. These criteria were pre-specified in advance of data collection to enhance the quality of the data used for our analyses and implemented prior to any investigations of the data (Abbey & Meloy, 2017). No other unusual response patterns were assessed.

The remaining responses to the attitude statements were entered into a principal component analysis (PCA). Varimax rotation was applied and the number of principal components (PCs) was determined from the Scree Plot based on the angle of inflection. Coefficients with an Eigenvalue below 0.30 were suppressed (Howard, 2016) and cross-loading items, defined as loading ≥0.30 on two or more factors, were removed (Costello & Osborne, 2005). Coherence within each PC was assessed using Cronbach's alpha, and each PC was summarised based on semantic reasoning.

The study sample was then described based on their reported intake frequency estimates, attitudes and demographic and lifestyle characteristics. One-way Multivariate Analysis of Covariance (MANCOVA) was selected to assess estimated intake frequencies across participant characteristics, while accounting for covariates. BMI groups were created based on the definitions provided by the UK National Health Service (2019): 'underweight', 'normal weight', 'overweight', 'obese' and 'morbidly obese'. All MANCOVAs considered gender, age and BMI as covariates, with the exceptions that the MANCOVA for the effect of gender on intake frequencies considered age and BMI as covariates, the MANCOVA for the effect of age on intake frequencies considered gender and BMI as covariates, and the MANCOVA for the effect of BMI on intake frequencies considered gender and age as covariates. Shapiro–Wilk tests were first conducted to evaluate normality and correlations were conducted to assess for multi-collinearity.

For aim 1, hierarchical multivariate linear regression analyses were conducted to assess associations between intakes and attitudes. Separate models were performed for each reported food intake variable and adjusted for participant characteristics. Demographic characteristics were entered in the first block, lifestyle characteristics in the second block and attitude components in the third block, all using the 'Enter' method.

For aim 2, Latent Profile Analysis (LPA) was undertaken to identify latent sub-populations within the sample in which different or dominant attitude combinations may exist (Oberski, 2016). The three-step approach outlined by Vermunt (2010) was undertaken. To build and estimate the optimal model, equal variances within and equal covariances across classes were assumed. Analytical Hierarchy Process was applied to incorporate Akaike's Information Criterion (AIC), Approximate Weight of Evidence (AWE), Bayesian Information Criterion (BIC), Classification Likelihood Criterion (CLC), and Kullback Information Criterion (KIC); in order to determine the optimal number of classes (Akogul & Erisoglu, 2017; Tein, Coxe, & Cham, 2013).

Basic linear models were used to investigate differences between the classes in attitude PC scores, each model adjusting for variables significantly correlated with that attitude PC. MANCOVA was conducted to assess estimated intake frequencies between the classes, adjusting for participant characteristics. Multinomial logistic regression analysis was then conducted to ascertain the effects of participant characteristics on likelihoods of being classified into one class versus another (Peng, Lee, & Ingersoll, 2010). For this analysis, genders were re-categorised as 'male' and 'not male', ethnic groups were re-categorised as 'white' and 'not white', education levels were re-categorised as 'at least a university degree' and 'no university degree' and SECs were re-categorised as 'at least professional occupations' and 'not professional occupations'.

MANCOVA, LPA and multinomial logistic regression analysis were performed using R statistical software (R Core Team, 2020; Rosenberg et al., 2019); remaining analyses were performed using SPSS (version 28). Statistical significance was set at $p = 0.05$. To control for type I error in multiple testing, significance thresholds for regression analyses and basic linear models were minimised to $\alpha' = 0.05$/number of tests (Jafari & Ansari-Pour, 2019). Upon a significant main effect, post-hoc Bonferroni tests were conducted. The analytic plan was pre-specified and any data-driven analyses are clearly identified and discussed appropriately.

3. Results

3.1. Participants characteristics

A total of 600 questionnaires were submitted. Of these, one questionnaire was incomplete, one participant failed the logical statements and 17 participants chose the option "neither agree nor disagree" for more than 50% of the statements.

Participant characteristics for the remaining 581 participants are described in Table 3. In total, 41.5% self-identified as male, 57.5% as female and 1.0% as non-binary; with ages ranging from 18 to 87 years. BMI ranged from 15.8 to 65.3 kg/m^2, 4.3% were classified as underweight, 44.8% as lean, 28.7% with overweight, 16.2% with obesity and 6.0% with morbid obesity. In addition, 11% of participants reported a health condition that could influence their eating and food choice, 15% of participants reported adhering to a weight management diet, and 14% of participants reported at least one food intolerance or allergy.

Compared to 2020 population estimates for the UK (Office for National Statistics, 2021), the study sample included more females (X^2 (2, N = 581) = 13.2, p < .01); more younger adults (X^2 (5, N = 581) = 216.0, p < .01); fewer individuals belonging to a Black ethnic group (X^2 (4, N = 581) = 30.6, p < .01); more adults with O levels, A levels, college diploma or equivalent and fewer with no formal education or a university degree (X^2 (5, N = 581) = 206.8, p < .01); more adults in SEC 2 or 4 and fewer in SEC 1 or 5 (X^2 (4, N = 581) = 159.9, p < .01); and more individuals with underweight, lean or morbid obesity and fewer with overweight or obesity (X^2(4, N = 581) = 75.9, p < .01).

3.2. Attitudes

After six iterations, six PCs were identified explaining in total 39.1% of the variance. PC1 explained 7.9% of the variance, PC2 explained

Table 3
Participant Characteristics – percentage (number) per category (N = 581).

Characteristic	Frequency	Percentage, % (N)
Gender	Male	41.5 (241)
	Non-binary	1.0 (6)
	Female	57.5 (334)
Age, years, mean ± SD	38.1 ± 15.2	
Ethnic Group	[1]White	91.0 (529)
	[2]Asian	2.9 (17)
	[3]Black	1.6 (9)
	Mixed or Multiple	3.4 (20)
	[4]Other	1.1 (6)
Highest education level	No Formal Qualifications	1.9 (11)
	O Levels/GCSEs – equivalent	19.3 (112)
	A Levels/Diploma – equivalent	44.8 (260)
	University Degree	18.2 (106)
	Postgraduate Degree	9.9 (58)
	Vocational or Other	5.9 (34)
NS-SEC	Class 1, %	26.7 (155)
	Class 2, %	26.2 (152)
	Class 3, %	7.7 (45)
	Class 4, %	16.9 (98)
	Class 5, %	22.5 (131)
BMI, kg/m^2, mean ± SD	26.5 ± 6.7	

White: British, Irish, Gypsy/Traveller, Roma and Other. [2] Asian: Bangladeshi, Chinese, Indian, Pakistani and Other. [3] Black: African, Caribbean and Other. [4] Other: Arab, other and prefer not to say. SD: Standard deviation. GCSE: General Certificate of Secondary Education. NS-SEC: National Statistics Socio-Economic Classification. BMI: Body Mass Index.

7.7%, PC3 explained 6.6%, PC4 explained 6.4%, PC5 explained 6.0% and PC6 explained 4.5% variance. The statements in each PC are given in Table 4. The factor loadings for each statement, and correspondence with the six themes from which the statements were developed are provided in the Supplementary Materials. Ten items did not load onto any factor with a coefficient >0.30 and 16 items cross-loaded on multiple PC's. These items were removed from subsequent analyses. These items are also listed in the Supplementary Materials.

PC1 consisted of 10 statements with a Cronbach's alpha of 0.81. The statements expressed that sugars, LNCS and sweet-tasting foods had an influence or impact on the individual, hence this component was named 'Personal Impact'. PC2 consisted of 13 statements with a Cronbach's alpha of 0.76. All statements included "I …" and an action, hence this PC was named 'Personal Management'. PC3 consisted of five statements with a Cronbach's alpha of 0.69. The statements expressed a sense of apathy or nonchalance; hence this PC was named 'Apathy'. PC4 consisted of seven statements with a Cronbach's alpha of 0.68. The statements expressed unfavourable or undesirable attitudes towards the food items, hence this PC was named 'Negativity'. PC5 consisted of eight statements with a Cronbach's alpha of 0.78. These statements were about knowledge and awareness; hence this PC was named 'Perceived Understanding'. PC6 consisted of five statements with a Cronbach's alpha of 0.66. The statements expressed ideas that one does not feel like one has the capacity to act in accordance with ones beliefs, goals or desires, largely as a result of external influences, hence it was named 'Perceived Nonautonomy'.

All variance inflation factors were below 4 and tolerance above 0.1, showing a sufficient lack of multi-collinearity (Tabachnick & Fidell, 2019). All independent variables were non-normally distributed ($p < .01$), except for PC3 ($p = .10$), thus Spearman's Rho was used to measure inter-correlations. Inter-correlation coefficients were all below rho = 0.70.

3.3. Estimated intake frequencies

Mean reported intake frequencies (times/day) of sugars, LNCS and sweet-tasting foods across demographic and lifestyle characteristics are provided in Tables 5 and 6 respectively. There were no statistically significant differences in reported intake frequencies between genders, age groups, ethnic groups and SECs (largest $F(20, 2288) = 1.49$, $p = .08$, Pillai's Trace = 0.05, partial $\eta^2 = 0.01$).

There was a statistically significant difference based on highest education level attained ($F(25, 2860) = 2.46$, $p < .01$, Pillai's Trace = 0.11,

Table 4
Attitude statements included in each PC.

PC	Attitude Statement
PC1: Personal Impact	I tend to crave sweet foods.
	I tend to crave sugars.
	I tend to crave sweeteners.
	I want to reduce my intake of sweet foods.
	The presence or absence of sweet foods in my diet influences my mood.
	The presence or absence of sugars in my diet influences my mood.
	The presence or absence of sweeteners in my diet influences my mood.
	I feel indifferent towards sweet foods.
	Sweet taste is physically addictive.
	Sugar is physically addictive.
PC2: Personal Management	When I consume sugars, I balance out my diet through exercising and/or eating other healthy foods.
	When I consume sweeteners, I balance out my diet through exercising and/or eating other healthy foods.
	When I consume sweet foods, I balance out my diet through exercising and/or eating other healthy foods.
	My choice and/or consumption of sugars depends on how much knowledge I have on them.
	My choice and/or consumption of sweeteners depends on how much knowledge I have on them.
	I only consume sweet foods during special occasions.
	I only consume sugars during special occasions.
	I only consume sweeteners during special occasions.
	I categorise my intake of sweet foods into "special" and "normal".
	My health or body image will determine whether I modify my sugar intake or not.
	My health or body image will determine whether I modify my sweet foods intake or not.
	My health or body image will determine whether I modify my sweeteners intake or not.
	The people that I am with (family, friends, colleagues) influence my intake of sweeteners.
PC3: Apathy	People are too concerned about cutting down on sweet foods.
	People are too concerned about cutting down on sugars.
	People are too concerned about cutting down on sweeteners.
	Sugar is not as bad as fat for your health.
	Adding sugar in food products is unnecessary.
PC4: Negativity	Sweeteners are worse for your health than salt.
	Sweeteners are physically addictive.
	Sweeteners are not as bad as fat for your health.
	Adding sweeteners in food products is unnecessary.
	I feel guilty whenever I consume sweeteners.
	Labels are misleading and deceptive.
	The food environment hinders me from reducing my intake of sweeteners.
PC5: Perceived Understanding	I know where to find credible information on sugars.
	I know where to find credible information on sweet foods.
	I know where to find credible information on sweeteners.
	If someone asks me, "what are sweeteners?", I am able to explain.
	If someone asks me, "what is sugar?", I am able to explain.
	I do not know whether to consume sugar or sweeteners.
	I know how to replace sugar with sweeteners in cooking/baking.
	I know what strategies or policies have been put in place to reduce sugar consumption in the UK.
PC6: Perceived Nonautonomy	Desire or need for sweet foods changes with age.
	Desire or need for sugar changes with age.
	Desire or need for sweeteners changes with age.
	It is impossible to completely eliminate sugar out of my diet.
	It is impossible to completely eliminate sweet foods out of my diet.

partial $\eta^2 = 0.02$), for reported frequency of adding sugar ($F(5,572) = 6.11, p < .01$). Individuals with no formal qualifications reported adding sugar more frequently than individuals with A-levels and above (smallest $t(269) = 2.21, p \leq .02$), and these individuals reported adding sugar more frequently than individuals with a postgraduate degree (smallest $t(316) = 3.18, p \leq .02$).

BMI groups differed in reported frequency of adding LNCS ($F(20, 2292) = 1.81, p = .02$, Pillai's Trace = 0.06, partial $\eta^2 = 0.02$; $F(4,574) = 3.84, p < .01$). Lean participants reported adding LNCS significantly less often than participants with morbid obesity ($t(293) = -3.94, p < .01$). All other BMI groups did not differ significantly (largest $t(200) = 1.83$), $p = .07$).

Adherence to a diet also had a significant effect ($F(5, 572) = 2.85, p = .02$, Pillai's Trace = 0.02, partial $\eta^2 = 0.02$; $t(579) = 2.73, p < .01$). Individuals who adhered to a diet reported adding sugar and consuming sugar-food groups less frequently than individuals who did not adhere to a diet ($t(579) = 2.18, p = .03$).

Presence of health condition or food allergy did not have significant effects on mean reported intake frequencies (largest $F(5, 572) = 0.87, p = .51$, Pillai's Trace = 0.01, partial $\eta^2 = 0.01$).

3.4. Aim 1: Individual attitudes

Regression results of the final models for all reported intake frequency estimates are given in Tables 7 and 8. Adding sugar more frequently was associated with greater agreement with statements on Personal Management ($\beta = 0.14$, $t(565) = 3.05$, $p < .01$).

Consuming sugar-food groups more frequently was associated with less agreement with statements that sugars, LNCS and sweet-tasting foods and their intakes had a Personal Impact ($\beta = -0.24$, $t(565) = -5.42$, $p < .01$), and with greater agreement with statements on Personal Management ($\beta = 0.19$, $t(565) = 4.13$, $p < .01$).

Consuming all sweet-tasting food groups more frequently was also associated with less agreement that sugars, LNCS and sweet-tasting foods and their intakes had a Personal Impact ($\beta = -0.25$, $t(565) = -5.74$, $p < .01$) and with greater agreement with Personal Management ($\beta = 0.15$, $t(565) = 3.28$, $p < .01$).

Negative associations with education also remained in the analyses on adding sugar ($\beta = -0.15$, $t(565) = -3.25$, $p < .01$), and reverse effects were found for adding honey ($\beta = 0.14$, $t(565) = 3.00$, $p < .01$). Consuming all sweet-tasting food groups more frequently was also positively associated with age ($\beta = 0.14$, $t(565) = 3.03$, $p < .01$). Earlier effects of BMI and adherence to a diet were removed on consideration of the attitudes.

Table 5
Reported intake frequencies[1] across demographic characteristics, mean ± SD (N = 581).

Demographic characteristics		Adding sugar[2]	Adding honey[2]	Adding LNCS[2]	Sugar-food groups[2]	Sugar-free food groups[2]	Total sweet food groups[2]
Gender	Male (n = 241)	1.33 ± 2.13	0.23 ± 0.81	0.58 ± 1.43	1.86 ± 2.00	0.22 ± 0.42	2.09 ± 2.07
	Non-binary (n = 6)	0.38 ± 0.62	0.01 ± 0.03	1.02 ± 2.51	1.79 ± 2.08	0.12 ± 0.23	1.90 ± 2.09
	Female (n = 334)	0.85 ± 1.72	0.25 ± 0.97	0.57 ± 1.64	1.78 ± 1.71	0.35 ± 0.83	2.13 ± 2.03
Age Group	18 to 24 (n = 241)	0.76 ± 1.24	0.30 ± 1.13	0.46 ± 1.56	1.65 ± 1.89	0.31 ± 0.78	1.96 ± 2.24
	25 to 34 (n = 73)	0.84 ± 1.66	0.42 ± 1.26	0.47 ± 1.14	1.70 ± 1.59	0.21 ± 0.26	1.91 ± 1.63
	35 to 44 (n = 134)	1.31 ± 2.23	0.19 ± 0.72	0.73 ± 1.79	1.84 ± 1.99	0.34 ± 0.71	2.18 ± 2.07
	45 to 54 (n = 107)	1.11 ± 2.02	0.24 ± 0.77	0.69 ± 1.67	1.87 ± 1.75	0.26 ± 0.70	2.13 ± 1.89
	55 to 64 (n = 69)	1.40 ± 2.54	0.06 ± 0.21	0.72 ± 1.54	2.11 ± 1.81	0.34 ± 0.82	2.45 ± 2.21
	65 above (n = 26)	0.96 ± 1.79	0.12 ± 0.22	0.03 ± 0.11	2.14 ± 1.70	0.25 ± 0.38	2.38 ± 1.78
Ethnic Group	White (n = 241)	1.06 ± 1.94	0.21 ± 0.80	0.58 ± 1.59	1.80 ± 1.77	0.29 ± 0.67	2.10 ± 1.94
	Mixed (n = 20)	0.82 ± 1.61	0.51 ± 1.53	0.78 ± 1.64	1.31 ± 1.19	0.33 ± 0.79	1.64 ± 1.53
	Asian (n = 17)	0.95 ± 1.81	0.47 ± 1.12	0.34 ± 0.94	1.59 ± 1.58	0.08 ± 0.16	1.67 ± 1.64
	Black (n = 9)	0.80 ± 1.37	0.34 ± 0.55	0.30 ± 0.32	3.10 ± 3.90	0.75 ± 1.62	3.86 ± 5.37
	Other (n = 6)	1.39 ± 1.09	1.44 ± 3.46	0.51 ± 0.61	3.36 ± 3.77	0.38 ± 0.57	3.74 ± 3.73
Education level	No formal (n = 11)	3.08 ± 3.29[c]	0.21 ± 0.60	0.84 ± 1.93	2.21 ± 2.19	0.21 ± 0.24	2.42 ± 2.12
	O levels[3] (n = 112)	1.54 ± 2.42[bc]	0.16 ± 0.62	0.88 ± 1.68	2.09 ± 2.27	0.27 ± 0.64	2.36 ± 2.45
	A levels[4] (n = 260)	1.14 ± 1.81[b]	0.19 ± 0.73	0.49 ± 1.46	1.60 ± 1.54	0.26 ± 0.57	1.86 ± 1.70
	Vocational[5] (n = 34)	0.74 ± 2.19[ab]	0.07 ± 0.28	0.50 ± 1.21	2.57 ± 2.39	0.21 ± 0.34	2.78 ± 2.36
	University (n = 106)	0.57 ± 1.29[ab]	0.35 ± 1.24	0.59 ± 1.91	1.77 ± 1.33	0.37 ± 0.84	2.14 ± 1.58
	Postgrad (n = 58)	0.30 ± 0.82[a]	0.54 ± 1.41	0.37 ± 1.03	1.86 ± 2.31	0.42 ± 1.07	2.28 ± 2.89
NS-SEC	NS-SEC 1 (n = 155)	0.63 ± 1.42	0.25 ± 0.79	0.52 ± 1.32	1.78 ± 1.61	0.34 ± 0.81	2.12 ± 2.01
	NS-SEC 2 (n = 152)	0.86 ± 1.45	0.24 ± 1.06	0.33 ± 0.86	1.85 ± 2.30	0.26 ± 0.43	2.11 ± 2.38
	NS-SEC 3 (n = 45)	1.07 ± 1.89	0.41 ± 1.31	0.75 ± 1.62	1.77 ± 1.40	0.24 ± 0.39	2.01 ± 1.59
	NS-SEC 4 (n = 98)	1.34 ± 2.36	0.33 ± 1.06	0.65 ± 1.73	1.74 ± 1.38	0.28 ± 0.51	2.01 ± 1.42
	NS-SEC 5 (n = 131)	1.52 ± 2.35	0.12 ± 0.40	0.82 ± 2.16	1.89 ± 1.93	0.32 ± 0.94	2.21 ± 2.22

[1]Times per day. [2] Within each column, frequencies labelled with different letters are different at $p < .05$, with Bonferroni correction, where 'a' always represents the smallest value. [3]O levels includes General Certificate of Secondary Education. [4]A levels includes Diploma. [5]Vocational includes prefer not to say. NS-SEC: National Statistics Socio-Economic Classification.

Table 6
Reported intake frequencies[1] across lifestyle characteristics, mean ± SD (N = 581).

Lifestyle characteristics		Adding sugar[2]	Adding honey[2]	Adding LNCS[2]	Sugar-food groups[2]	Sugar-free food groups[2]	Total sweet food groups[2]
BMI group[3]	Underweight (n = 25)	1.04 ± 1.91	0.43 ± 1.71	0.42 ± 1.24[ab]	2.53 ± 3.14	0.33 ± 0.86	2.85 ± 3.59
	Normal (n = 260)	1.02 ± 1.75	0.29 ± 1.05	0.37 ± 1.10[a]	1.70 ± 1.68	0.25 ± 0.55	1.95 ± 1.76
	Overweight (n = 167)	1.16 ± 2.16	0.24 ± 0.74	0.74 ± 1.57[ab]	1.74 ± 1.75	0.28 ± 0.54	2.01 ± 2.01
	Obese (n = 94)	1.11 ± 2.11	0.12 ± 0.40	0.62 ± 1.97[ab]	1.99 ± 1.66	0.46 ± 1.15	2.46 ± 2.11
	Morbidly Obese (n = 35)	0.94 ± 1.70	0.13 ± 0.53	1.36 ± 2.73[b]	2.09 ± 2.41	0.23 ± 0.27	2.32 ± 2.39
Health[4]	Yes (n = 65)	0.76 ± 1.49	0.26 ± 0.86	0.85 ± 2.11	1.65 ± 1.23	0.28 ± 0.42	2.14 ± 1.12
	No (n = 516)	1.08 ± 1.95	0.24 ± 0.91	0.54 ± 1.47	1.84 ± 1.90	0.30 ± 0.72	1.93 ± 1.30
Diet[5,6]	Yes (n = 88)	0.54 ± 1.20[a]	0.16 ± 0.57	0.71 ± 1.62	1.43 ± 1.34[a]	0.42 ± 0.98	2.16 ± 2.06
	No (n = 493)	1.14 ± 2.00[b]	0.26 ± 0.95	0.55 ± 1.55	1.89 ± 1.90[b]	0.27 ± 0.62	1.85 ± 1.96
Allergy	Yes (n = 80)	0.96 ± 1.79	0.17 ± 0.36	0.54 ± 1.75	1.48 ± 1.42	0.23 ± 0.47	2.18 ± 2.12
	No (n = 501)	1.06 ± 1.93	0.25 ± 0.96	0.58 ± 1.53	1.87 ± 1.89	0.31 ± 0.72	1.72 ± 1.42

[1]Times per day. [2] Within each column, frequencies labelled with different letters are different at $p < .05$, with Bonferroni correction, where 'a' always represents the smallest value. [3] Participants with a BMI below 18.5 kg/m^2 were classified as with 'Underweight', within the range of 18.5–24.9 kg/m^2 as with 'Normal weight', within the range of 25–29.9 kg/m^2 as with 'Overweight', within the range of 30–39.9 kg/m^2 with 'Obesity', and of 40 kg/m^2 or above with 'Morbid Obesity'. [4]Any health condition that could influence their eating and food intake choice. [5]Any weight management diet. [6]Within each column, frequencies labelled with different letters are different at $p < .05$.

Table 7
Regression results for the final model per outcome (N = 581).

		Adding sugar per day					Adding honey per day					Adding LNCS per day				
		β	*t*	*p*	R^2	F-statistic	β	*t*	*p*	R^2	F-statistic	β	*t*	*p*	R^2	F-statistic
Demographics	(Constant)		2.49	.013	.06	$F(5,575) = 7.81$, $p < .01$		0.16	.873	.02	$F(5,575) = 3.76$, $p < .01$		−1.28	.201	.01	$F(5,575) = 1.16$, $p = .33$
	Gender[a]	−0.04	−0.85	.395			0.01	0.10	.924			0.02	0.32	.747		
	Age	0.07	1.65	.100			−0.08	−1.85	.064			0.02	0.47	.639		
	Ethnic Group[b]	−0.02	−0.38	.703			0.08	1.86	.063			0.02	0.47	.637		
	Highest qualification	−0.15	−3.25	**.001**			0.14	3.00	**.003**			0.01	0.10	.921		
	NS-SEC	0.07	1.46	.145			0.01	0.30	.763			0.08	1.73	.085		
Lifestyle	BMI	−0.04	−0.87	.384	.06	$F(4,571)_{change} = 1.88$, p = .11	−0.02	−0.52	.604	.02	$F(4,571)_{change} = .87$, p = .48	0.11	2.55	.011	.01	$F(4,571)_{change} = 2.56$, p = .04
	Health	−0.06	−1.50	.134			0.04	0.81	.417			0.03	0.60	.549		
	Allergy	0.06	1.33	.185			−0.07	−1.62	.106			0.02	0.35	.724		
	Diet	−0.05	−1.24	.214			−0.02	−0.45	.654			0.04	0.92	.359		
Attitudes (PC)	1: Personal Impact	−0.05	−1.07	.286	.09	$F(6,565)_{change} = 4.45$, p < .01	0.05	1.14	.253	.04	$F(6,565)_{change} = 2.63$, p = .02	−0.06	−1.37	.172	.02	$F(6,565)_{change} = 2.11$, p = .05
	2: Personal Management	0.14	3.05	**.002**			−0.01	−0.11	.910			−0.04	−0.88	.381		
	3: Apathy	0.07	1.62	.106			0.11	2.52	.012			0.06	1.36	.173		
	4: Negativity	0.11	2.46	.014			−0.01	−0.06	.953			0.11	2.56	.011		
	5: Perceived Understanding	−0.08	−1.92	.055			−0.11	−2.56	.011			0.05	1.05	.295		
	6: Perceived Nonautonomy	0.02	0.51	.609			−0.01	−0.15	.883			−0.03	−0.78	.438		

[a] Gender: male (1), non-binary (2) and female (3).
[b] Ethnic group: White and non-White. *B*: Unstandardised B. S.E.: Standard Error. B: Standardised Beta. NS-SEC: National Statistics Socio-Economic Classification. PC: Principal Component. p-value passed α′ threshold = .004.

Table 8
Regression results for the final model per outcome (N = 581).

		Sugar-food groups per day					Sugar-free food groups per day					All sweet food groups per day				
		β	*t*	*p*	R^2	F-statistic	β	*t*	*p*	R^2	F-statistic	β	*t*	*p*	R^2	F-statistic
Demographics	(Constant)		2.33	0.20	.01	F(5,575) = .79, *p* = .56		−1.42	.157	.01	F(5,575) = 1.80, *p* = .11		1.61	.109	.01	F(5,575) = 1.73, *p* = .13
	Gender[a]	−0.03	−0.62	.536			0.08	1.65	.100			0.01	0.06	.952		
	Age	0.12	2.71	.007			0.06	1.21	.226			0.14	3.03	**.003**		
	Ethnic Group[b]	0.03	0.82	.410			0.04	1.02	.309			0.09	2.26	.024		
	Highest qualification	0.02	0.37	.711			0.08	1.69	.092			0.03	0.70	.484		
	NS-SEC	−0.04	−0.85	.393			0.06	1.21	.226			−0.02	−0.47	.642		
Lifestyle	BMI	−0.05	−1.26	.210	.01	$F(6,565)_{change}$ = 1.74, *p* = .14	0.04	0.97	.333	.01	$F(6,565)_{change}$ = 1.78, *p* = .13	−0.03	−0.70	.484	.01	$F(6,565)_{change}$ = 1.47, *p* = .21
	Health	−0.04	−0.96	.337			−0.04	−0.88	.382			−0.05	−1.12	.265		
	Allergy	−0.06	−1.32	.188			−0.06	−1.27	.206			−0.07	−1.64	.101		
	Diet	−0.04	−1.00	.320			0.07	1.60	.111			−0.01	−0.30	.763		
Attitudes (PC)	1: Personal Impact	−0.24	−5.42	**<.001**	.07	$F(6,565)_{change}$ = 8.27, *p* < .01	−0.12	−2.60	.009	.02	$F(6,565)_{change}$ = 2.03, *p* = .06	−0.25	−5.74	**<.001**	.08	$F(6,565)_{change}$ = 7.69, *p* < .01
	2: Personal Management	0.19	4.13	**<.001**			−0.05	−1.06	.290			0.15	3.28	**.001**		
	3: Apathy	0.05	1.20	.230			−0.03	−0.76	.451			0.03	0.74	.462		
	4: Negativity	0.04	0.87	.384			0.02	0.34	.737			0.04	0.96	.338		
	5: Perceived Understanding	−0.01	−0.16	.874			0.07	1.61	.109			0.02	0.52	.601		
	6: Perceived Nonautonomy	−0.02	−0.37	.709			0.05	1.15	.250			0.01	0.14	.893		

[a] Gender: male (1), non-binary (2) and female (3).
[b] Ethnic group: White and non-White. *B*: Unstandardised B. S.E.: Standard Error. B: Standardised Beta. NS-SEC: National Statistics Socio-Economic Classification. PC: Principal Component. p-value passed α′ threshold = .004.

3.5. Aim 2: Profiles of multiple attitudes

Applying the analytic hierarchy process, the best solution was a 3-class model. This model also fitted significantly better than an empty or null model (likelihood ratio χ^2: 85.3, $p < .01$). The AIC, AWE, BIC, CLC and KIC of different models are provided in the Supplementary Materials.

The three classes differed in their scores across the attitude PCs (Table 9). Individuals in class 1 felt low Personal Impact from sugars, LNCS and sweet-tasting foods, some Personal Management, low Apathy, low Negativity, low Perceived Understanding, and high Perceived Non-autonomy over their intakes of these food items. Individuals in this class were therefore described as 'Feeling Ill-equipped'. Individuals in class 2 reported high Personal Management, some Apathy, Negativity, and Personal Impact, highest Perceived Understanding and lowest Perceived Non-autonomy; thus, individuals in this class were characterised as 'Actively Engaged'. Finally, individuals in class 3 experienced all attitudes to some degree, and to a degree between the other two classes; hence, individuals in this class were described as 'Unopinionated'. Further description of all response patterns is presented in Fig. 1.

3.5.1. Intake frequencies of latent attitude class groups

The three classes differed in some of the reported intake frequencies (Table 10). Participants who were classified as Feeling Ill-equipped (Class 1) reported adding LNCS less frequently than participants who were classified as Actively Engaged (Class 2), ($t(212) = -2.14, p < .01$); and reported consuming all sweet-tasting food groups more frequently than the participants classed as Unopinionated (Class 3), ($t(417) = 2.65$, $p < .01$).

3.5.2. Demographic and lifestyle characteristics of latent attitude groups

The demographic and lifestyle characteristics of the three classes of participants are provided in the Supplementary Materials. The multinomial logistic regression model performed significantly better than the null model (likelihood ratio $\chi^2 = 67.7$, $p < .01$), was statistically significant (χ^2 (4, N = 581) = 57.0, $p < .01$), explained 13.4% of the variance in attitudes, and correctly classified 66.6% of cases.

Associations with demographic characteristics are shown in Table 11. Individuals who were classified as Feeling Ill-equipped were older (β = 0.04, $\chi^2 = 3.26$, $p < .01$), and had a higher educational attainment (β = 1.12, $\chi^2 = -2.89$, $p < .01$), than those who were classified as Actively Engaged. Individuals who were classified as Unopinionated were also older than those who were classified as Actively Engaged (β = 0.02, $\chi^2 = 3.16$, $p < .01$).

4. Discussion

This study aimed to 1) examine the relationships between specific attitudes and reported intakes of sugars, LNCS and sweet-tasting foods; and 2) identify attitude profiles towards these food groups, together with individual characteristics. Principal component analysis revealed six different individual attitudes in our data set: 'Personal Impact', 'Personal Management', 'Apathy', 'Negativity', 'Perceived Understanding' and 'Perceived Non-autonomy', and latent profile analysis revealed three underlying consumer profiles of attitudes: 'Feeling Ill-equipped', 'Actively Engaged', and 'Unopinionated'.

4.1. Aim 1: Individual attitudes

In relation to self-reported intakes, two individual attitudes were found to be important; firstly a greater agreement with statements relating to Personal Management was associated with adding sugar, consuming sugar-food groups and consuming sweet-tasting food groups more frequently, and secondly, a greater agreement with statements on Personal Impact was associated with consuming sugar-food groups and sweet-tasting food groups less frequently. Statements in the Personal

Table 9
Mean ± SD scores for all attitudes in the three classes (N = 581).

Score for each component	Class 1 (n = 52) Feeling Ill- equipped	Class 2 (n = 162) Actively Engaged	Class 3 (n = 367) Unopinionated	F-statistic
Personal Impact	−0.49 ± 0.4 [a]	−0.20 ± 0.4 [b]	−0.21 ± 0.4 [b]	8.24 *
Personal Management	0.10 ± 0.3 [ab]	0.15 ± 0.3 [b]	0.07 ± 0.3 [a]	5.86 *
Apathy	−0.62 ± 0.4 [a]	−0.17 ± 0.4 [b]	−0.20 ± 0.4 [b]	7.70 *
Negativity	−0.51 ± 0.3 [a]	0.07 ± 0.3 [b]	0.03 ± 0.3 [b]	15.60 *
Perceived Understanding	−0.55 ± 0.4 [a]	0.42 ± 0.3 [c]	−0.33 ± 0.3 [b]	146.00 *
Perceived Nonautonomy	0.09 ± 0.5 [c]	−0.45 ± 0.4 [a]	−0.29 ± 0.4 [b]	24.00 *

Within a row, the highest score is underlined and scores with different letters are different at $p < .05$, with Bonferroni corrections, where 'a' always represents the smallest value. *$p < .01$.

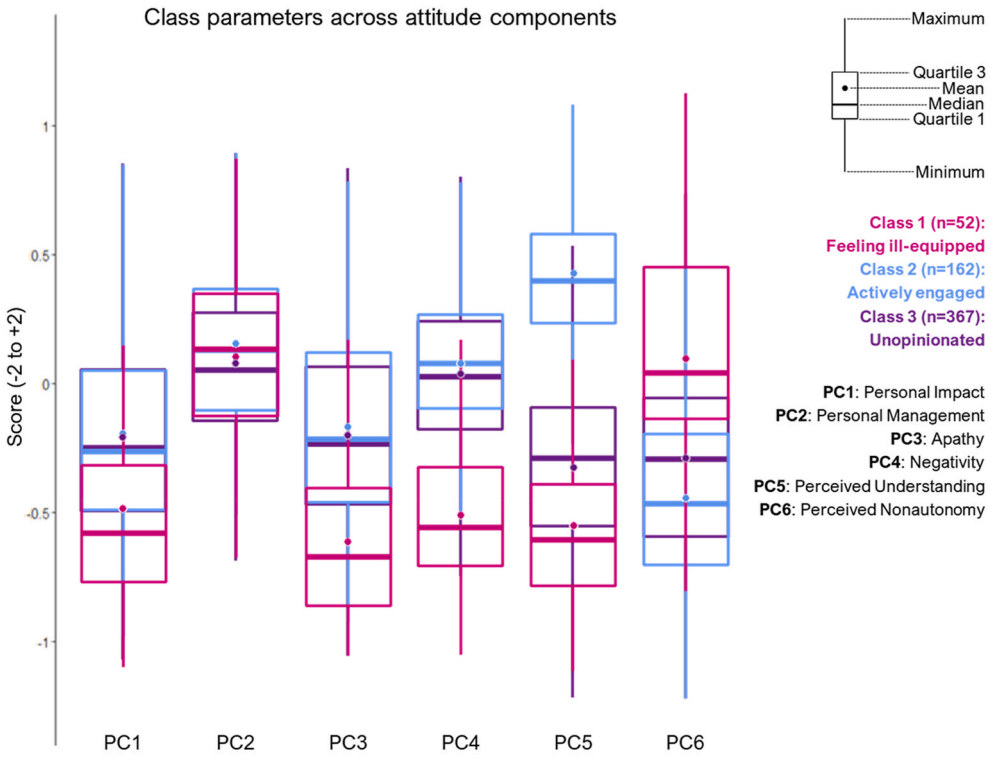

Fig. 1. Response patterns to the attitude components based on a 3-Class Model.

Management PC, all made reference to the self, to include, for example, 'When I consume sweet foods, I balance out my diet through exercising and/or eating other healthy foods', 'My choice and/or consumption of sugars depend on how much knowledge I have on them' and 'I only consume sweet foods during special occasions'. This PC has a strong suggestion of cognitive, rational or reasoned control, and our positive associations between Personal Management and higher reported intakes suggest either that people who consume sugars, LNCS and sweet-tasting foods more frequently feel better able to manage and control this and/or have strategies to mitigate or compensate for this consumption; or that people who feel able to manage their intakes permit themselves to consume more. Conversely, statements in the Personal Impact PC referred to impacts on mood, cravings and physical addiction, for example, 'The presence or absence of sweet foods in my diet influences my mood' and 'I tend to crave sweet foods'. This PC has a more affective basis, and our negative associations between Personal Impact and reported intakes suggest that people who consume sugars, LNCS and sweet-tasting foods more frequently feel that they are less impacted by this affective dimension, or that people who feel more affected, tend to consume them less frequently. Katou et al. (2004) also made a distinction between cognitive and affective perceptions toward sugars, although in their study cognitive perceptions were more about the considered impacts of sugars on health, rather than abilities to manage these. Interestingly, however, they also found that affective perceptions were associated with intakes. A distinction between cognitive and affective reactions to sweet taste is interesting.

The four additional attitudes identified in the current study, namely Apathy, Negativity, Perceived Understanding and Perceived Non-Autonomy, have all been described before, but unlike in other studies, none of these other attitudes, when considered individually, were associated with reported intakes. Chen and House (2022) reported consumers with attitudes similar to 'Apathy' to be uninterested in and unlikely to consume healthy foods, Sylvetsky, Greenberg, Zhao, and Rother (2014) report associations between increased 'Negativity' and lower sweetener usage, and individuals with attitudes similar to 'Autonomy' have been reported to consume less sugar or sugar-food groups (Morel et al., 2019; Palmedo and Gordon., 2019). Reported associations with 'Perceived Understanding' are more mixed, with some studies reporting positive associations between perceived health benefits and sugar, LNCS or sugar-sweetened food intakes (Hennessy et al., 2015; Morel et al., 2019; Pielak et al., 2019), and some studies reporting no associations (Fadupin et al., 2015; Zytnick et al., 2015). Our findings suggest that these attitudes, when considered individually, have no association with sugars, LNCS and sweet-tasting food intakes in a UK sample.

Table 10
Reported estimated intake frequencies across classes (N = 581).

No. of times *per* day	Class 1 (n = 52) Feeling Ill-equipped	Class 2 (n = 162) Actively Engaged	Class 3 (n = 367) Unopinionated	$F_{(2,569)}$	p^1
Adding sugar	0.68 ± 1.5	0.94 ± 1.6	1.14 ± 2.1	0.88	0.41
Adding honey	0.30 ± 0.7	0.19 ± 0.7	0.26 ± 1.0	0.65	0.52
Adding LNCS	0.16 ± 0.5 [a]	0.72 ± 1.9 [b]	0.57 ± 1.5 [ab]	3.48	0.03
Sugar-food groups	2.27 ± 2.1	1.88 ± 2.1	1.72 ± 1.7	2.58	0.08
Sugar-free food groups	0.44 ± 1.2	0.35 ± 0.9	0.25 ± 0.5	1.63	0.20
All **sweet food groups**	2.71 ± 2.7 [b]	2.23 ± 2.41 [ab]	1.98 ± 1.73 [a]	3.45	0.03

[1] Represents the p-value associated with the main effect of class membership on each of the intake frequency, having adjusted for all characteristics. Within a row, individual frequencies labelled with different letters are different at $p < .05$ with Bonferroni corrections, where 'a' always represents the smallest value.

Table 11
Results of the multinomial logistic regression model (N = 581).

Feeling ill-equipped [a]	B	S.E.	Wald's χ^2	*p*	e^{β} (O. R.)
(Intercept)	−3.20	0.88	−3.63	<0.001	0.04
Male	0.33	0.37	−0.89	0.373	1.40
Age	0.04	0.01	3.26	0.001	1.04
White ethnic group	−1.45	0.62	2.36	0.018	0.23
At least university degree	1.12	0.39	−2.89	0.004	3.05
At least professional occupation	−0.02	0.37	0.04	0.967	0.98
BMI	0.04	0.02	1.78	0.076	1.04
Presence of health condition	0.14	0.52	0.26	0.794	1.15
Presence of diet	0.82	0.42	1.97	0.048	2.27
Presence of allergy	1.03	0.46	2.26	0.024	2.81
Being unopinionated [a]	**β**	**S.E.**	**Wald's χ^2**	***p***	***e*** $^{\beta}$ **(O. R.)**
(Intercept)	0.54	0.51	1.05	0.295	1.71
Male	0.59	0.22	−2.67	0.007	1.81
Age	0.02	0.01	3.16	0.001	1.02
White ethnic group	−1.06	0.44	2.42	0.016	0.35
At least university degree	0.64	0.24	−2.65	0.008	1.89
At least professional occupation	−0.26	0.21	1.23	0.218	0.77
BMI	−0.01	0.02	−0.05	0.962	1.00
Presence of health condition	0.27	0.35	0.77	0.442	1.31
Presence of diet	0.08	0.29	0.28	0.779	1.09
Presence of allergy	0.50	0.33	1.53	0.126	1.66

[a] Class 2 – Actively engaged (n = 162) was the reference category due to it being the 'preferred' attitude. S.E.: standard error. O.R.: Odds Ratio. Wald's χ^2: Z-score. *p*: of 2-tailed Z test. p-value passed α' threshold = 0.006.

4.2. Aim 2: Profiles of multiple attitudes

When all attitudes were considered together, three latent consumer profiles were found. These profiles were labelled: Feeling Ill-equipped, Actively Engaged, and Unopinionated; and described 52, 162 and 367 individuals, respectively. Similar profiles have previously been found in the literature, as below, although none of these studies focused on sugar, LNCS or sweet food consumption. Chen and House (2022) identified a "passionately involved" class of contemporary food shoppers in the US, similar to the "Actively Engaged" profile, and several researchers report "uninvolved" (Chen & House, 2022), "unengaged" (Van Huy, Chi, Lobo, Nguyen, & Long, 2019), and "uncommitted" consumers (Żakowska-Biemans, 2011) in their sample populations. Although termed differently, these groups were all described as being disconnected or detached from involvement with foods and food intakes. The high proportion of individuals in the "Unopinionated" profile may suggest a lack of interest in sugars, LNCS and sweet-tasting foods by the UK public, an observation that may be concerning for Public Health England, but it is noteworthy that these consumers report the least frequent consumption of sugars, LNCS and sweet-tasting foods.

In relation to intakes, those who were classed as Actively Engaged reported adding LNCS more frequently than those classed as Feeling Ill-equipped and those Feeling Ill-equipped reported consuming all sweet-tasting food groups more frequently than those classed as Unopinionated. Compared to those classed as Feeling Ill-equipped, individuals who were classed as Actively Engaged scored higher in Perceived Understanding, higher in Personal Impact, Apathy and Negativity and lowest in Perceived Non-autonomy. Compared to those classed as Unopinionated, individuals who were classed as Feeling Ill-equipped scored highest on Perceived Non-autonomy, and lower on Personal Impact, Apathy, Negativity and Perceived Understanding. The combination of understanding and autonomy has also been reported previously in relation to healthy food intakes (Kell, 2008; Leong, Madden, Gray, & Horwath, 2012).

4.3. Sugar, sweetener and sweet-tasting food consumption

Taken together with the results on individual attitudes, our findings suggest that sugar and sugar-sweetened food consumption are associated with perceptions of personal management and limited affective impact; LNCS consumption is associated with a collection of attitudes characterised predominantly by increased perceived understanding and perceived autonomy; and sweet-tasting food consumption is associated with perceptions of personal management, limited affective impact, and a collection of attitudes characterized predominantly by perceptions of low understanding and low/non-autonomy.

In relation to sugar reduction, strategies for reducing free sugar consumption would benefit from more understanding of the personal management and personal impact attitudes. It would be valuable, for example, to understand if intakes are actually managed, either through cognitive restriction or through compensatory strategies, such as undertaking physical activity. A more comprehensive analysis of the diet and additional eating and health behaviours would be needed for this. Alternatively, individuals may not be managing their intakes at all, this may be a perception only. This association may suggest a need for greater awareness of the amount of sugar contained in foods, of dietary recommendations and of the amount of sugar that may be required for effects on health. Some research demonstrates a lack of awareness of sugar guidelines (Prada et al., 2020), and other researchers also suggest a need for more education (Fadupin et al., 2015; Forde & Solomon-Moore, 2019; Gase et al., 2014; Gupta et al., 2018; Hennessy et al., 2015; Morel et al., 2019; Ortega-Avila et al., 2019; Palmedo & Gordon, 2019; Pielak et al., 2019), but the nature and exact purpose of this desired education is often unclear.

Greater reported sugar and sugar-food intakes were also associated with limited experience of affective impact. Increased awareness and education on the effects of sugars, LNCS and sweet-tasting foods on mood and well-being may reduce these effects. Some care may be needed, however, given the greater agreement in our study that sugars and sweet-tasting foods are addictive and can elicit cravings, and this has been reported elsewhere (Morel et al., 2019; Tang et al., 2021). Fear appeals and the use of extreme or dichotomous suggestions can also result in unhealthy perceptions towards foods (Forde & Solomon-Moore, 2019; Morel et al., 2019; Swift et al., 2018). Education on the effects of sugars for physical health may also encourage reduced consumption, or increased awareness of the pleasure and well-being that can be gained from sugar and sweet-tasting foods in smaller portions.

LNCS, rather than sugar, consumption was associated with more active engagement with the sugar agenda, characterised by greater perceived understanding and autonomy. Perceived understanding reflected how well individuals perceived their abilities to acquire, comprehend and apply insights on sugars, LNCS and sweet-tasting foods, thus education may encourage this more active engagement. Perceived autonomy reflects perceptions of free will, thus strategies to empower individuals to make these choices may also help, e.g., through increased availability.

Finally, sweet-tasting food consumption was associated with personal management, personal impact, limited understanding and autonomy. Education on sugar can be offered as above, and suggestions to empower individuals can include providing clear concrete information on sugar content, education on the alternatives to sugar and sweet-tasting foods, and strategies to counter demands or norms for sugar and sweet food consumption in specific contexts (Morel et al., 2019; Ortega-Avila et al., 2019; Palmedo & Gordon, 2019; Pielak et al., 2019; Swift et al., 2018; Tang et al., 2021). Care may be needed as increased perceptions of management were associated in our data with increased intakes, however, a shift towards greater autonomy and having true understanding, may not only improve sugar intakes, but may also improve support for sugar reduction strategies (Traina, Martinussen, & Feiring, 2019). Support for differing strategies for reducing sugar consumption, including product labelling, taxation and product reformulation is known to differ between individuals (Hagmann et al., 2018; Prada et al., 2020), and increasing support will likely lead to increasing impact (Hagmann et al., 2018; Pell et al., 2019; Prada et al., 2020).

Parts of this discussion reflect the interrelated nature of all attitudes. Individuals can hold different attitudes concurrently, as demonstrated in a smaller sample of UK consumers (Tang et al., 2021) and in earlier studies (Fadupin et al., 2015; Forde & Solomon-Moore, 2019; Hennessy et al., 2015; Ortega-Avila et al., 2019; Palmedo & Gordon, 2019; Pielak et al., 2019; Zytnick et al., 2015). This may also explain why the relationship between attitudes and intakes has been reviewed as 'weak or inconsistent' (Gupta et al., 2018, p. 192). Notably also, while attitudes and groups of consumers were created in our study, these attitude groupings have limited association with sugar, LNCS and sweet-tasting food intakes. Differing attitudes may also reflect the differences between sugar, LNCS and sweet-tasting food intakes as behaviours. LNCS usage can be motivated by factors other than sugar consumption (Morel et al., 2019), and sugar reduction does not necessarily require LNCS use (Sylvetsky et al., 2014); thus, some consumers may have diverse attitudes towards and motivations for consuming sugar and LNCS, such that LNCS cannot substitute for sugars (Tang et al., 2021). Importantly, individuals appear to have differing needs, and therefore, either multiple strategies are needed for an entire population, or some tailoring to individuals may be useful.

Unique needs across individuals are also demonstrated by our latent consumer groups. According to our latent profiles, greatest differences between the groups were found in perceived understanding, perceived non-autonomy and in the strength of all attitudes. Those classed as Feeling Ill-equipped were characterised by higher non-autonomy, low perceived understanding and low levels of all attitudes. These individuals may benefit particularly from increased empowerment, increased education and increased awareness of sugar-related concerns. Those classed as Unopinionated were characterised by a lack of opinions or attitudes, or attitudes that were neither positive nor negative. These individuals may also benefit from increased education and awareness. Those classed as Actively Engaged were characterised by greater perceived understanding and lower perceived non-autonomy. Some education may be beneficial to ensure understanding is accurate, but a reduction in autonomy would likely not be desirable. Thus, a range of personalised approaches may be needed to reduce free sugar intakes in different groups.

4.4. Associations with demographic and lifestyle characteristics

Some associations with demographic characteristics were also found. In the analyses of individual attitudes, adding sugar more frequently was also associated with a lower educational attainment, adding honey more frequently was associated with a higher educational attainment, and individuals consuming all sweet-tasting foods groups more frequently were older. In the analyses on attitude profiles, participants who were classed as actively engaged were younger than those who were classed as feeling ill-equipped and those classed as unopinionated. Actively engaged participants were also less educated than those who felt ill-equipped. Similar associations with age can be found in the literature (Aljassim & Ostini, 2020; Andrus & Roth, 2002; Chen & House, 2022). Our findings for educational attainment are somewhat mixed. Higher educational attainments are often associated with healthier diets (Aljassim & Ostini, 2020; Andrus & Roth, 2002; Turrell & Kavanagh, 2006), as found in our analyses of individual attitudes, and in other samples, a latent class of 'passionately involved' consumers had mostly attained college or postgraduate education and held more professional occupations (Chen & House, 2022). Other researchers also report similar associations between educational level and interest in foods and their intakes (Alonso, O'Neill, & Zizza, 2012; Boles et al., 2014; Gase et al., 2014; Pielak et al., 2019). While perceived understanding would appear to be important along with other attitudes, our findings may reflect a lack of association between formal education and dietary knowledge in the UK, particularly in relation to sugar consumption.

BMI and adherence to a diet were initially also associated with reporting adding LNCS to coffee, tea and homecooked dishes more frequently, and consuming sugar-food groups less frequently, but these effects were removed on consideration of the attitudes. Associations between sugar consumption, LNCS consumption, BMI and dieting have been previously reported (Appleton & Conner, 2001; Fadupin et al., 2015; Morel et al., 2019). Our data suggest, however, that these associations are the result of underlying attitudes. Differing attitudes towards sugars, LNCS and sweet-tasting foods dependent on BMI and dependent on dieting status have also previously been found (Appleton & Conner, 2001; Morel et al., 2019).

Our associations with demographic characteristics suggest benefit for sugar reduction strategies from targeting those who are older. These strategies may further be particularly effective as older individuals are known to be more concerned by health and more likely to consume healthier diets than those who are younger (Pielak et al., 2019).

4.5. Strengths and limitations

Strengths of our study include our large and diverse study sample, the use of a questionnaire developed from earlier qualitative work, the concurrent investigation of sugars, LNCS and sweet-tasting foods, and the use of two methods for assessing associations between attitudes and intakes. Our sample, however, was not representative of the UK population at the time of the study, thus generalization to the UK population may not be possible or valid. Our assessments of intake further were self-reported and based on frequency estimates rather than estimates of amount. Self-report measures of food intake can be prone to bias as a result of under-reporting (Krebs-Smith et al., 2000; Ravelli & Schoeller, 2020), and some research suggests under-reporting specifically of sugar-sweetened foods (Krebs-Smith et al., 2000; Ravelli & Schoeller, 2020). Regarding our frequency estimate, sweet-tasting food intake particularly may be poorly represented by merely summing the frequency of consumption of sugar- and sugar-free food groups. Dietary measures such as food dairies or 24-h recalls would aid in more accurate assessments of dietary sweet taste intake. In both our intake measures and attitude statements we also combined different sugars, LNCS and sweet-tasting foods. We defined our terms at the start of the questionnaire to encompass all sugars, LNCS and sweet-tasting foods, but attitudes, particularly, may differ for individual sugars, LNCS or sweetened

foods (Prada et al., 2021). Attitudes may also be subject to social desirability or other biases related to self-report and individual cognitions. We recognise also, that while attitudes may be associated with intakes, or with some intakes and in some individuals, behaviour takes place within a context and this context must always be considered when suggesting and designing strategies for change (Gase et al., 2014; Gupta et al., 2018; Hennessy et al., 2015).

5. Conclusion

This work investigated attitudes towards sugars, LNCS and sweet-tasting foods in a sample of the UK public, associations between these attitudes and intakes of these food groups and the dominance of these attitudes based on individual characteristics. Using a questionnaire based on earlier qualitative work, six attitudes towards these foods were found: 'Personal impact', 'Personal Management', 'Apathy', 'Negativity', 'Perceived Understanding' and 'Perceived Non-autonomy'. Of these, greater agreement with statements relating to Personal Management was associated with adding sugar, consuming sugar-food groups and consuming all sweet-tasting food groups more frequently, and greater agreement with statements on Personal Impact was associated with consuming sugar-food and sweet-tasting food groups less frequently. Further work to investigate these two attitudes will provide a view to offering practical recommendations that would be of value. Three latent sub-populations with distinct combinations and strengths of attitudes were also identified: 'Feeling Ill-equipped', 'Actively Engaged' and 'Unopinionated'. In relation to intakes, individuals who were classed as Actively Engaged added LNCS more frequently than those who were classed as Feeling Ill-equipped, and those classed as Feeling Ill-equipped consumed sweet-tasting food groups more frequently than those classed as Unopinionated. These profiles suggest some benefits may be gained for differing sub-groups, particularly from increasing education, increasing awareness and empowerment. Age and education level were also associated with both individual attitudes and attitude profiles. Associations between differing attitudes, attitude profiles, intakes and demographic characteristics suggest value for a number of personalised approaches for reducing free sugar intakes.

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Ethical statement

The study was granted ethical approval by the Research Ethics Committee of Bournemouth University (ID: 32878) prior to commencement and was run in accordance with the ethical guidelines of the British Psychological Association and the Declaration of Helsinki. All participants provided informed consent prior to participation.

CRediT authorship contribution statement

Claudia S. Tang: Conceptualization, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing, Project administration. **Monica Mars:** Funding acquisition, Supervision, Writing – review & editing. **Janet James:** Funding acquisition, Supervision, Writing – review & editing. **Katherine M. Appleton:** Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing.

Declaration of competing interest

C.S.T. and J.J. declare that they have no competing interests.

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Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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