APPETITIVE BEHAVIOURS ARE HERITABLE PHENOTYPES ASSOCIATED WITH ADIPOSITY

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In a seminal paper published in 1968, Schachter proposed that obesity—in humans or rats—was caused by an "external" eating style consisting of high responsiveness to external cues such as the smell or taste of food and low responsiveness to internal cues for satiety.[1] He introduced a design that went on to become a cornerstone of appetite research, in which obese and normal-weight participants carried out "taste tests" on two separate days. For each test, they were provided with a large supply of crackers and invited to eat as much as they wished while completing the taste ratings. On one day, the test was preceded by a meal (termed a "preload"), while on the other there was no preload. In the normal-weight group, cracker consumption was lower in the preload than the no-preload condition, but there was no such compensation in the obese group. Schachter concluded that this lack of compensation in the obese indicated a lack of satiety sensitivity. He also assessed responsiveness to external cues using a variety of designs, including comparing the quantity eaten from "taste test" foods that varied in palatability. Consumption was augmented more strongly by high palatability in obese than normal-weight groups, indicating greater responsiveness to taste cues.

Externality Theory was overtaken by a shift in the focus of eating behaviour research as a result of evidence suggesting that dietary restraint (practiced by most obese people) was the primary cause of abnormalities of appetite.[2] This was supported by findings indicating that an external eating style also was observed in normal-weight restrained eaters.[3] However, in recent years there has been a resurgence of interest in the idea that individual differences in appetite (including satiety responsiveness, food responsiveness, and the reward value of food) may be related to the development of excess weight. This idea has gained support following the observation that the severe monogenic forms of obesity all involve abnormalities of appetite.[4]

In an extension of externality theory, I hypothesised that individual differences in appetite are heritable behavioural phenotypes that are quantitatively related to adiposity rather than being associated specifically with obesity. In this model, lower satiety responsiveness and higher food cue responsiveness are not simply characteristics of the obese, but are individual-level risk factors for positive energy balance whose expression depended on the broader food environment. In environments where food is readily accessible and highly palatable, this would translate into higher food intake—and therefore greater weight gain—in those with the strongest food responsiveness and the weakest satiety sensitivity. This phenotype-environment interaction model is consistent with the huge increases in obesity prevalence that have been observed in recent years, and with the fact that weights have increased much more at the upper than the lower end of the BMI distribution.[5]

Research in my group has focused particularly on children; partly because of the importance of identifying modifiable behavioural characteristics before significant weight gain has set in, but also because young children are less susceptible to dietary restraint. We have also extended the

methods of assessing appetite by developing a psychometric measure, which has made it feasible to collect data from much larger samples.

Using established behavioural paradigms, we have shown that caloric compensation in a preload study conducted over five occasions in a sample of 5-7 year olds (n = 115) is significantly negatively correlated with BMI-SD scores (r = -.26). In another sample (7-8 year olds; n = 350), we used the "Eating in the Absence of Hunger" (EAH) paradigm (where children are offered unlimited access to highly palatable food after they have eaten to satiety), and showed a significant positive association with BMI-SDS, with a strong gradient in consumption in boys from the underweight, through lower and higher normal-weight, to the overweight and obese. In another study with 9-11 year old twins (n = 254) tested in their homes, we assessed the speed of eating during a standard meal. Eating speed has been hypothesised to be a measure of avidity of appetite, while the rate of deceleration during a meal has been proposed as a marker of satiety. The children were given a meal of sandwiches and fruit and videotaped as they ate. Bite frequency was significantly correlated with BMI-SDS and was progressively higher across lower normal-weight, higher normal-weight, and overweight/obese groups, but there was no association between adiposity and rate of deceleration.

We have been unable to find associations between the reward value of food and adiposity in either 7-8 year olds or 9-11 year olds. However, the measure that we used was difficult to implement and may not have provided an adequate test. Nonetheless, these null findings raise the possibility that these phenotypes are more prominent in clinically obese children, and as such, may be consequences of attempts at weight control rather than aetiological factors.

We designed the Child Eating Behaviour Questionnaire (CEBQ) to assess a number of aspects of appetite that have been linked with obesity, including satiety responsiveness, slowness in eating, enjoyment of food, food cue responsiveness, emotional overeating, and emotional undereating. It is a parent-completed measure that has been demonstrated to be reliable, internally consistent, associated with measured food intake in behaviour tests, and stable from ages 4 to 11.[6-8]

We used two sub-scales from the CEBQ (satiety responsiveness/slowness in eating and enjoyment of food) to examine associations with BMI-SDS in two samples of children, a large sample (n = 10,364) of 9-11 year old twins in which the anthropometric measures were taken by the parents, and a smaller sample of 3-5 year olds (n = 572), with anthropometric measures taken by researchers. Parents completed the CEBQ (for both children in the twin sample) and returned it by post. Satiety responsiveness was negatively correlated with BMI-SDS (twins: r = -.22; pre-schoolers: r = -.19), and enjoyment of food was positively correlated (twins: r = .19; preschoolers: r = .18). Both appetite variables not only differed between overweight and normal-weight groups, but also discriminated within the normal-weight group, with the thinnest children having the lowest enjoyment of food and the highest satiety responsiveness.[9] We also showed that these two appetitive traits were independently associated with adiposity when included in the same predictive model.

The use of a twin sample allowed us to assess the heritability of appetite by comparing the similarity of pairs of identical (MZ) and non-identical (DZ) twins. We had already demonstrated

that BMI and waist circumference were highly heritable in this sample.[10] The CEBQ results showed similarly high heritability for both satiety responsiveness and enjoyment of food, with a modest and non-significant shared environment effect.[11] Eating speed showed a similar magnitude of heritability in the smaller sample of twins who completed this behavioural task.

These results support the hypothesis that heritable eating behaviour phenotypes are quantitatively related to adiposity. Future research will address the phenotypic overlap between the different aspects of appetite, assess whether common genes influence appetite and adiposity, investigate associations between appetite and established weight-related genes (e.g., *FTO*), and explore the scope for intervention to modify appetitive styles to minimise weight gain.

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