Food Choice Phenotypes: A Tool to Study Food Selection?

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Abstract

Food selection provides a scientific arena for both ideographic and nomothetic approaches to understanding human functioning: the search for individuality and the search for general rules. The contrast between individual variability and common characteristics becomes important when one seeks to understand how genetic expression and cultural influence interact. One strategy that may be helpful is the identification of phenotypes. A start on this has been made in relation to food selection, energy balance and body weight regulation. In the field of obesity research, a number of metabolic and morphological phenotypes have been useful. Behavioural phenotypes relating to the selection of nutrients or patterns of food intake could provide equally powerful tools.

In principle, a number of behavioural phenotypes could be defined based on taste preferences (for foods), patterns of eating, or motivational responses. Because of the importance of dietary fat to energy balance and body weight regulation, researchers have paid attention to the habitual consumption of high-fat or low-fat foods. These have now been well defined and can be termed phenotypes. The phenotype is defined by a particular pattern of behaviour characterised by the selection of high-fat or low-fat food items. These phenotypes show different patterns of appetite control, strength of cues for the regulation of meals and control of hunger. In addition, the phenotypes differ in physiological parameters such as basal metabolic rate (BMR), respiratory quotient (RQ) (expected), leptin levels, resting heart rate and sleeping patterns. The phenotype has only been studied intensively in young adult males.

These phenotypic behaviour patterns could be construed as an environmentally driven diet selection leading to physiological adaptations, or as a biologically driven metabolic profile leading to a particular diet selection. Some light may be shed on this issue by the identification of gene variants linked to a particular pattern, or by the disclosure of familial clusters of phenotypes. These behavioural phenotypes may provide useful tools to examine the interaction between biology (genes) and environment (culture) in the establishment of patterns of food selection.

What is food selection?

The selection and consumption of foods represent one of the most important patterns of behaviour that define human actions. The foods we choose to consume are associated with psychological, biological and economic consequences. The expression of this form of behaviour represents an interaction between biological processes and environmental contingencies. However, the phenomenon of food choice itself does not represent a unitary entity. We can distinguish between secular trends in the patterns of foods consumed, which have been traced over scores of years in large-scale populations. These trends—for example in the consumption of the macronutrients fat and carbohydrate—tell us something about the "average" behaviour within large groups. In turn, we can seek explanations for this average or normative behaviour. However, this type of analysis does not tell us what a particular individual may choose to eat for a particular meal on a particular occasion—this is another type of question and a different type of food selection. Consequently, we should not expect a single or simple answer to the question "What is food selection?" In reality, there are different approaches to the issue of food selection, each of which will add to an understanding of the global issue.

Just as there is no single entity that defines food selection, so there will not be a single explanatory process. Although it can be claimed that a pattern of behaviour reflects the integration of biology and culture, some forms of food selection will be either entirely biologically driven or culturally explained. For example, the restriction placed on the eating of particular animals by certain religious groups does not require a biological explanation; it is culturally determined.

However, an interesting area which offers the potential for biological or environmental explanation would be the causes underlying opposing types of food selection within the same cultural and economic group. It is in this area that food choice phenotypes may be useful tools to explore the processes underlying the pattern of behaviour, and to investigate the consequences of a habitual dietary intake.

Finally, we should ask what defines food selection. Is it the actual food that is ingested or the attitude toward or intention to eat a set of foods? Is food selection nothing more than a subjective expression of preferences? What is the relationship between food selection and taste preference? It is clear that behaviour, intentions, preferences and tastes may all contribute to an understanding of food selection, and each will be linked to a particular experimental methodology. It appears then that an understanding of food selection will accrue through the accumulated knowledge of different ways in which humans interact with foods.

Functional Phenotype Approach

The approach described here is based on the identification of behavioural phenotypes. A phenotype is normally defined as a stable cluster of measurable characteristics, which separate one "type" from another. This "type" is classically regarded as the consequences of a particular genotype. The approach, therefore, lends itself to the development of a taxonomy of unambiguously defined "types"; it is therefore a typology. In principle a number of phenotypes could be defined based on taste preferences (for foods), patterns of eating, beliefs about foods or motivational responses. The approach favoured here emphasises behaviour, since this can be defined more rigorously and unambiguously than attitudes or subjective perceptions.

The power of this approach resides in the capacity to make clear distinctions between different phenotypes, that is, between groups of individuals with contrasting and habitual patterns of food selection. In turn, the term "selection" is defined rigorously by reference to foods that are actually consumed. These phenotypes can be distinguished according to habitual dietary intakes (of foods that have been "selected"). Because of the importance of dietary fat to energy balance, body weight regulation and other aspects of health (1) we have initiated this approach to food selection through the study of high-fat and low-fat phenotypes.

Measurement Issues in Food Selection Behaviour: How do we know what foods people eat?

Any investigation of actual food selection in natural, free-living subjects must face the problem of the accuracy of measurement of food intake behaviour. A dilemma for nutritional science has developed related to this issue; this has been termed a "misreporting" problem, the most common form of which is under-reporting (2). When subjects are brought into a laboratory or research unit, experimental control makes it possible to record accurately the amount and type of food consumed. Food intake can be measured directly. The problem is that eating in these rather sterile environments may be quite different to the eating that occurs under natural circumstances. Measurement in the real world requires an indirect rather than a direct approach — that is, it relies on some type of self-report or self-monitoring. Unfortunately, and surprisingly, many people find it very difficult to report accurately the foods they habitually consume on a daily basis (3).

Naturalness vs. Precision

A major methodological issue for understanding food choice clearly rests upon the type of behaviour to be observed and the type of data collected. Food choices measured in a laboratory or research unit can be recorded accurately and precisely; but they may differ from the choices freely made when people are in their normal environments. On the other hand, food choice measures under "free-living" conditions may be elusive to detect and record with any degree of precision; but they do reflect "natural" behaviour. This dilemma can be represented as the balance between naturalness and precision. In all studies there will be a trade-off between these two desirable attributes of the food choices being measured.

Therefore, in practice, the food choices being described reflect a compromise.
For many researchers (but not all) the natural food choices in a normal environment represent the pattern of greatest interest. However, this type of behaviour is difficult to measure with assurance, and widely accepted that the recording of this behaviour is prone to under-reporting. An example of this can be seen in the records of people choosing foods high in sugar or high in fat. In the field of obesity research there is an active debate concerning the relative contribution of high-fat or high-sugar foods to the development of obesity. Interestingly, some epidemiological data (4) have confirmed the existence of the sugar-fat seesaw. This means that obesity is associated with high fat/low sugar intakes, and leanness with the converse. A similar phenomenon can be seen in the analysis of another large database (5). However, in these analyses it is important to minimise the effect

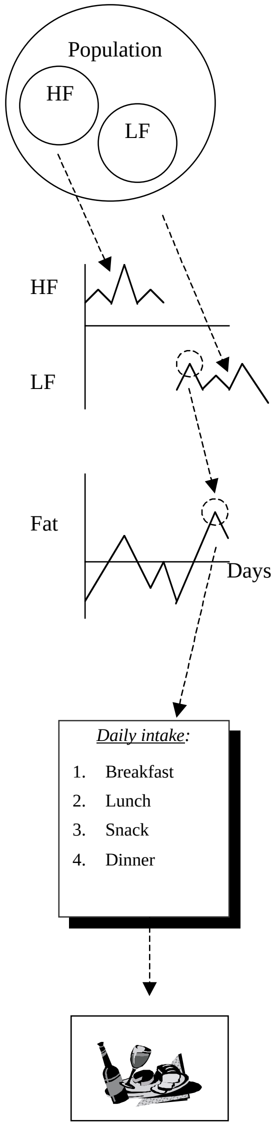
of misreporting. This can be done by establishing a threshold value for the subjective records of energy intake such that estimates below this value can be regarded as being physiologically implausible. By convention, this threshold is set at 1.2 x RMR (where RMR is normally calculated from equations). When "under-reporters" were excluded from the data base, analysis indicated that sugar intakes remained constant in lean, normal-weight, overweight and obese subjects. However, fat intakes rose as the degree of obesity increased (5). When the analysis was directed to particular types of foods (sweet and fatty foods) as opposed to the intakes of nutrients (sucrose and fat), the degree of under-reporting had a major impact upon the interpretation of the data. Analysis of the "plausible" dietary records indicated that the most obese women consumed the highest amounts of sweet/fat foods. However, if the entire group of subjects were analysed (including the under-reporters) the obese women appeared to consume the smallest quantities of sweet/fat foods (5).

This type of outcome means that when food-selection phenotypes are being identified, it is essential to assess the degree of under-reporting. Any records derived from food frequency questionnaires (FFQs) or food diaries which showing physiologically implausible energy intakes should lead to those subjects being excluded (even though they may show interesting food selection patterns).

High-Fat and Low-Fat Phenotypes

High-fat (HF) and low-fat (LF) phenotypes are classified according to the type of diet habitually consumed, measured by FFQ and diary record, with under-reporters excluded. The records indicate that these groups habitually consume different types of foods and display different patterns of eating (6). The research strategy is designed to allow individuals characterised in a population by their macronutrient intakes to be tracked so that their particular food choices and consumption of specific foods can be identified (see Figure 1).

In principle, phenotypes can be identified independently of age or sex. However, in a first series of studies the characteristics of young adult males have been examined. When subjected to energy and macronutrient challenges in order to eval-



1. Establishment of the average intakes of high- and low-fat consumers:

BETWEEN GROUP variation

2. Comparison between individuals within Groups (HF & LF):

BETWEEN INDIVIDUAL variation

3. Comparison of the individual day-to-day variation in fat intakes:

WITHIN INDIVIDUAL variation

4. *HIGH FAT PATTERNS* (episodes)

5. Comparison of foods eaten in single high fat meals:

HIGH FAT FOODS

Figure 1 - Plan of the sequential analysis of high- and low-fat consumers from their identification in the population sample (1), through the groups' comparison based on percentage daily fat intakes (2), the day-to-day variation within any particular individual (3), and finally for the description of individual eating patterns (and patterns of fat intake) within one day (4), and the identification of specific foods within meals (5).

uate the responses of the appetite control system, clear differences between the HF and LF groups were demonstrated. Initially, HF displayed higher initial hunger levels, with a much sharper decline in hunger in response to meals or nutrient loads (7). After eating, hunger recovered more rapidly in HF compared with LF. In addition, the size of a test meal consumed was closely related to the suppression of hunger in HF; in contrast, the appetite response system in LF appeared to be somewhat insensitive and damped. This relationship between habitual fat intake and hunger is reminiscent of a previous finding. French et al (8) found that during two weeks of high-fat overfeeding to normal-weight subjects, which caused a significant gain in weight, subjects displayed a progressive increase in hunger and a decrease in fullness before a test meal. Taken together, these findings may indicate that eating a high-fat diet facilitates feelings of hunger.

A further feature of these behaviour studies was that HF and LF differed in the control over meal size when offered an unlimited range of either high-fat or high-carbohydrate foods. HF consumed a similar weight of food on both diets, and therefore took in a much higher amount of energy with the high-fat (high-energy-dense) foods. In contrast, LF consumed a much smaller amount of the high-fat foods, and consequently took in a similar amount of energy on both diets. These findings suggest that signalling systems for meal termination (satiation) and post-meal inhibition of appetite (satiety) operate with differing strengths in HF and LF. This finding may not be surprising in view of the fact that the gastrointestinal tract has become adapted to dealing with quite different dietary components, and this factor will have exerted a priming effect on specific satiety signals.

The existence of distinctive profiles of appetite control in HF and LF phenotypes indicates different patterns of physiological responses to food ingestion. The possibility of other physiological differences was investigated using indirect calorimetry for BMR, RQ and dietary-induced thermogenic responses to specific fat and carbohydrate loads (9).

The results indicated that HF have a lower RQ than LF; this finding confirmed that fat oxidation was higher in HF, as would be expected due to the habitual high intake of fat-containing foods. However, an unexpected finding was the significantly higher BMR in HF compared with LF, together with different profiles of "thermogenic" responses to the high-fat and high-carbohydrate loads (see Table 1). A further important finding was that HF had higher plasma leptin levels than LF (10), despite having similar levels of body fat.

TABLE 1 - ANTHROPOMETRIC, DIETARY AND METABOLIC CHARACTERISTICS OF MALE HIGH- AND LOW-FAT PHENOTYPES (9)

Phenotype …	High-fat	Low-fat
Age (years)	20.5	20.6
BMI (kg/m^2)	22.6	22.1
Body fat (%)	9.9	9.8
Dietary fat intake:		
g/d	158.8	80.8*
% energy	44.3	32.0*
BMR (MJ/d)	6.80	6.10*
Resting RQ	0.84	0.89*
Plasma leptin (ng/ml)	2.92	1.79*

* Values were significantly different from those for the high-fat phenotype (two-tail): P<0.05.
BMI = Body Mass Index BMR = Basal Metabolic Rate

Indications for Energy Balance and Food Choice

A particular behavioural and physiological profile has been demonstrated from the study of HF and LF. The picture poses interesting questions, since these particular cohorts of young adult male subjects display markedly different intakes of dietary fat (159g/d *v* 81g/d) and energy. However, despite these large differences, subjects had almost identical body weights, BMI and fat masses. An obvious implication is that some aspect of energy expenditure or metabolism is balancing the high-energy intake so as to maintain body weight. The observation that HF and LF differ in BMR is consistent with this idea, although the absolute size of the energy difference does not appear sufficient to preserve energy balance. It should be noted that the relationship between BMR and weight control is variable. A low BMR predicts weight gain, whereas obesity is characterised by a BMR that is proportional to the lean body mass (11).

However, the notion of individuals with different BMR is consistent with the concept of "energy-sparing" and "energy-profligate" individuals, which has been used to describe two distinct groups of women (12). Interestingly, these two types of individuals are associated with different habitual intakes, the marginally-nourished and the very-well-nourished. For years some researchers in the field of obesity research have maintained the idea that individuals exist who are capable of consuming prodigious amounts of food yet remain lean. It is possible, therefore, that the HF and LF may constitute a useful investigative approach for examining the relationship between energy intake and energy utilisation, (13).

In conclusion, the measurable differences in the types of foods habitually selected pose the question of whether the "choices" are biologically driven (by particular tissue needs, physiological requirements or neuro-sensory characteristics) or incidentally "picked-up" from the environment. In either case it will be necessary for the physiological system to adapt to the ingestion of large amounts of specific macronutrients. Because food choices represent a balance between biological and environment processes, distinctive phenotypes characterised by extreme patterns of food choice behaviour and nutrient intakes can provide useful tools to investigate the relationship between food attributes, subjective food preference, taste preferences and actual eating (of the foods chosen).

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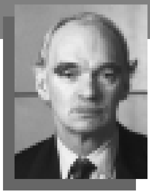

Biography

John E. Blundell

John Blundell currently holds the Chair of PsychoBiology at the University of Leeds. His early study was in Psychology and his later training was in Neuroscience at the Institute of Neurology in London. He has been active in research on the mechanisms of appetite control for more than 25 years.

The early research was concerned with the operation of brain centres then known as the hunger and satiety centres. During the upsurge of pharmacological and neurochemical investigations during the 1970s John Blundell was instrumental in establishing a role for the neurotransmitter serotonin in appetite control. One landmark paper from that period has since become a citation classic. Research on the effect of serotonin on human food intake and eating patterns is still continuing and involves work on obese patients and anti-obesity drugs.

About 15 years ago the Human Appetite Research Unit was established at Leeds University. The purpose of this unit is the investigation of mechanisms underlying the control of human appetite. Investigations are supported by the MAFF, research councils (BBSRC), industrial partners in the nutrition and pharmaceutical sectors, the Leeds Community Mental Health Trust and other agencies, such as the Sports Council of the UK and the British Technology Group. Current projects are examining a number of mechanisms of satiety signalling, the characteristics of high and low fat consumers identified in the Leeds community (The Leeds High Fat Study), the effects of structural differences in types of fat on satiety, the role of proteins and peptides in appetite control, the effect of gastric hormonal mechanisms, role of serotonin in the control of fat intake, the effect of the amount and intensity of exercise on appetite control and taste preference, the analysis of behavioural phenotypes, and the genetics of appetite control and food preferences. The group is heavily involved in the concept of nutriceuticals for appetite, mood and cognitive performance. The research group is a major partner in a new EU Framework IV programme on resistance and vulnerability to dietary-induced body weight gain.

These studies have scientific importance and practical relevance. The goal of research is to develop procedures for the healthy control of appetite in the school, clinic, home and workplace. A collaboration with the Yorkshire Centre for Eating Disorders (YCED) is examining the genetics and psychobiology of anorexia nervosa, bulimia and other eating disorders. The Leeds PsychoBiological model has been used successfully in the treatment of patients with bulimia nervosa. (Didasco Clinic, Verona). The LISS intervention trial has implications for the reduction of fat and saturated fat as recommended in dietary guidelines. These procedures all contribute to the development of a healthy appetite control, the promotion of healthy regulation of body weight and the prevention of weight gain as envisaged by the `Health of the Nation'.

John Blundell is an enthusiastic runner and has competed in races in UK, USA, Netherlands, Sweden and Switzerland. He is a director, trustee and member of the Board of Governors of the BBSRC Institute of Food Research, a member of the scientific governors of the British Nutrition Foundation, and serves on several other national and international committees.

Web: http://www.psyc.leeds.ac.uk/staff/johneb.html