

Symposium on ‘Molecular mechanisms and psychology of food intake’

Cues to overeat: psychological factors influencing overconsumption

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Human food intake is driven by necessity, but modern industrialized societies are characterized by food surfeit and an increasingly ‘obesogenic’ environment. This environment tends to discourage energy expenditure and to facilitate energy intake. The amount eaten in any given eating episode depends less on internal need state and more on environmental contextual factors such as the availability of highly-palatable energy-dense foods. In addition, the process of satiation can easily be disrupted by the introduction within a meal of different foods (variety effect), the presence of others (social context) and competing tasks (distraction). Properties of ingestants such as alcohol promote food intake and characteristics of individuals make them more or less susceptible to situational cues to overeat. In the present review the role of each of these environmental factors in promoting overconsumption is considered and the extent to which these factors might contribute to long-term weight regulation is discussed.

Overconsumption: Energy intake: Weight regulation: Environmental factors

Human food intake is motivated by need, but influenced by a myriad of complex factors including those that reside within the environment (availability, variety, portion size), those that characterize the food itself (energy density, macronutrient composition, sensory features) and the response of the individual to these factors. Most industrialized countries and many developing nations are now facing an exponential rise in overweight and obesity that must largely be a result of changes in the food environment. The relatively high levels of genetic predisposition to gain weight (Loos & Bouchard, 2003) in permissive environments suggest that the characteristics of the obesogenic environment and the response of the consumer to this environment must be understood if the obesity epidemic is to be tackled. In order to expose elements of the environment that may promote overeating, it is important to identify those controls of ingestion likely to be influenced by the food environment and then to examine how these features operate to derail homeostatic controls.

Direct and indirect controls of meal size

The brain receives a constant stream of information to guide food intake based on stored energy as well as current

energy and nutrient sources (Woods, 2005). Thus, the amount eaten within a meal will depend both on the metabolism of previous meals and the currently-available food. However, there is no simple relationship between energy deficit and energy intake. For example, consumers in Western cultures tend to eat their smallest meals after the longest period of energy depletion and their largest meal at the end of the day, in anticipation of this deficit (Weingarten, 1986). Meal size does not correspond well with the immediately preceding inter-meal interval (Le Magnen, 1969), suggesting that meal size is highly variable and subject to the influence of many different factors somewhat uncoupled from specific energy deficits (Wiepikema, 1971; Lowe & Levine, 2005). The variability of meal size indicates that there are a number of situational factors that can contribute to the amount of food consumed on any one occasion.

In order to conceptualize the controls of food intake in a clear and objective way, Smith (1996) has proposed that there are direct controls that only relate to the process of food stimuli engaging gastrointestinal mucosal receptors during eating and indirect controls that encompass all other cues. Signals arising from the gut provide both orosensory positive feedback and post-ingestive negative feedback

during the eating episode. Orosensory feedback stimulates eating whilst post-ingestive feedback inhibits eating (Smith, 2000). During the meal positive orosensory stimulation declines whilst negative feedback increases (Wiepkema, 1971). The meal ends when negative feedback exceeds or meets the strength of positive feedback (Smith, 1996).

By applying sham-feeding procedures in animal models, in which positive orosensory stimulation is intact but negative feedback is absent, the relative impact of orosensory and gastric feedback in controlling meal size can be determined. The sham-feeding model has also been used to investigate the neuromodulation of direct controls of meal size. For example, it has been shown that central administration of neuropeptide Y, a powerful orexigenic agent, affects meal size by increasing the volume of sucrose solution ingested as well as increasing the frequency and rate of licks in sham feeding compared with normal feeding (Torregrossa *et al.* 2006). Thus, neuropeptide Y serves to amplify orosensory stimulation to eat.

Similarly, the application of pyloric cuffs and/or infusions of nutrients directly into the stomach, bypassing orosensory inputs, allows the specific effect of negative gastric feedback to be assessed during a meal. Thus, under these conditions it has been shown that intake of a sweetened milk in rats is reduced by a relatively large volume (12 ml) of either saline (9 g NaCl/l) or milk infusions compared with smaller volumes (3 ml, 6 ml; Eisen *et al.* 2001). It is interesting to note that in this example reduction of intake does not depend on the nutrient content of the infusion but specifically relates to the larger volume size, suggesting a mechanical threshold for distension cues (Eisen *et al.* 2001). This finding has been confirmed in human subjects receiving intragastric infusions of milk-based liquid preloads (Rolls & Roe, 2002). In both lean and obese women increasing volume (from 200 to 400 ml) but not increasing energy (from 834 kJ (200 kcal) to 1668 kJ (400 kcal)) was shown to suppress appetite and food intake. In contrast, intragastric infusions of 425 ml high-fat or high-carbohydrate soup (Cecil *et al.* 1999) reduced appetite but not food intake. Correspondingly, in human subjects the distension of either the antrum or fundus, achieved using a gastric balloon, is insufficient even at high volumes of saline (300–800 ml) to reduce food intake, despite increasing subjective fullness and reducing hunger sensations (Oesch *et al.* 2006). These data indicate that gastric feedback is sufficient to suppress subjective appetite but does not always produce concomitant reductions in food intake. Thus, sham feeding and direct gastric delivery of nutrients allow comparison of the respective roles of positive orosensory stimulation and negative gastric feedback in determining meal size. Evidently, gastric feedback in the absence of orosensory cues is relatively weak at reducing food intake in human subjects (Cecil *et al.* 1999; Oesch *et al.* 2006).

Indirect controls include all other factors that do not directly engage with mucosal receptors, e.g. metabolic, hormonal, cognitive, social and environmental factors. These controls exert their effects on meal size by affecting the potency of direct controls (Smith, 1996, 2000). To assess the relative potency of direct and indirect influences on food intake, researchers have examined features of the

food (sensory characteristics, volume, energy density, portion size), features of the consumer (BMI, dietary restraint, eating habits) and features of the environment (presence of others, presence of competing tasks). It is clear that for human subjects indirect controls can override normal regulatory processes in determining meal size. This situation has obvious theoretical and applied implications for research and practice in understanding appetite regulation. Some of these implications are considered in the present review in the context of cues that promote over-consumption.

Characteristics of the food: the example of variety

During a meal, and long before the food is fully digested and absorbed, satiation processes begin to slow and ultimately to terminate eating. There is therefore a delay between the initiation of eating and the digestion and absorption of nutrients from the gut. Satiation must depend on at least some pre-absorptive mechanisms that increase in strength during the meal and help signal meal termination. It is not clear, however, to what extent satiation is entirely pre-absorptive, since changes in glucose and insulin release occur immediately in response to the sight, smell and thought of food during the cephalic phase of ingestion (Powley, 2000). These changes are likely to facilitate satiation. For example, Langhans *et al.* (2001) have shown that infusion of glucose or glucose and insulin into the hepatic portal vein during a meal attenuates spontaneous feeding in the rat. Apparently, there are cephalic-phase pre-absorptive processes that provide rapid feedback contributing to satiation. Sensory-specific satiety is a process that begins during eating, but before absorption takes place, and also facilitates meal termination.

Sensory-specific satiety is a phenomenon in which the pleasantness of an eaten food declines during the meal whilst preserving or enhancing the pleasantness of other foods (Rolls, 1986). Thus, the pleasure derived from consumption of a particular food is relatively high in the early stages of the meal and gradually declines during the course of eating. Sensory-specific satiety occurs immediately after eating, in the early pre-absorptive stages of ingestion, and does not rely on gastric feedback. It has been demonstrated when foods are sham fed (Rolls & Rolls, 1997; Smeets & Westerterp-Plantenga, 2006), when the food is merely smelled for the same duration as a normal meal (Rolls & Rolls, 1997) and for foods with very low energy densities (Rolls *et al.* 1988*a,b,c*). However, it is not known whether sensory specific satiety achieved under sham-feeding conditions will have an impact on energy intake, since not all sham-feeding experiments have offered participants the opportunity to consume a meal after the sham-feeding procedure. Nevertheless, Rolls & Rolls (1997) have reported that in a small sample of ten participants who rinsed (but did not swallow) coffee or orange juice, both sensory-specific satiety and reduced ingestion of the rinsed drink were found. This finding provides preliminary evidence that sensory-specific satiety in the absence of any gastric feedback is sufficient to influence intake, at least in the short term.

Sensory-specific satiety predicts lower intake of the eaten food compared with consumption of other foods. Thus, if offered the same food again this food is less likely to be eaten than if sensorially-different foods are offered (Rolls *et al.* 1984). Providing foods that differ only in flavour promotes intake by between 10 and 15%, but presenting foods that differ in flavour, texture and macronutrient content increases energy intake by 40% compared with offering the same food (Rolls & Hetherington, 1989). Thus, greater variety along differing dimensions (sensory and nutritional) promotes greater stimulation of intake. This effect may be related to habituation processes.

In a series of elegant experiments Epstein and his colleagues (for a review, see Raynor & Epstein, 2001) have examined the effect of variety on salivary habituation. Salivation in response to the presentation of a food stimulus declines with repeated presentation (Epstein *et al.* 1992); however, when a different food is introduced during the session the result is dishabituation to the stimulus (Temple *et al.* 2006). Thus, when children are presented with olfactory cues from a cheeseburger saliva secretion in response to the stimulus declines over seven trials, but this trend is reversed in the group provided with a different food (French fries) in the eighth trial. This change in salivation is mirrored in motivated responding for either the cheeseburger or the French fries (Temple *et al.* 2006). Thus, variety maintains interest in eating by preserving both the salivary response to food and motivated responding to obtain the food, compared with presenting just one food repeatedly.

Variety may stimulate food intake by a number of different mechanisms, including dishabituation of salivary response. Variety maximizes pleasure (positive orosensory feedback) and sustains appetite, whereas consuming a single food facilitates satiation. Introducing many different sensory features within a meal may stimulate eating through extending positive orosensory feedback.

The relative effects of volume (which promotes negative gastric feedback) and variety (which may enhance orosensory positive feedback) on meal size have recently been examined (Norton *et al.* 2006). Thirty men and women on four occasions received a low-volume (females 240 ml, 3.6 kJ/g; males 300 ml, 3.6 kJ/g) or high-volume (females 480 ml, 1.8 kJ/g; males 600 ml, 1.8 kJ/g) tomato soup 30 min before a sandwich lunch with either a single or variety of fillings. Reported hunger and fullness indicated a difference by volume, which suggests that the participants were sensitive to the immediate effects of volume on subjective appetite. However, the satiety quotient (change in subjective ratings of hunger, fullness, desire to eat divided by weight of soup consumed) calculated just before lunch indicated a smaller satiety quotient for the high-volume soup than for the low-volume soup. Thus, the reported satiety quotient for the high-volume soup is weaker, indicating some sensitivity to the energy density of the preloads. Despite the differences in subjective ratings by volume, there is no effect on the intake at lunch, thus intakes following the low-volume and high-volume soup preloads are similar. However, access to a variety of sandwich fillings produces a greater intake (by 14%) compared with providing sandwiches with a single filling regardless

of previous volume ingested. Thus, under these conditions the orosensory stimulation provided by variety is more important than the differences in gastric distension produced by alterations in volume.

It has been suggested that the effect of a volume manipulation may also depend on energy density exceeding a certain threshold (Gray *et al.* 2002). The lower satiety quotient obtained for the high-volume soup in the previous experiment suggests that this threshold was not reached; thus, per g soup consumed, the high-volume low-energy density preload failed to reduce intake at lunch. Under these conditions, increasing sensory variety (positive feedback) has a reliable and marked impact on energy intake in the short term, regardless of previous ingestion of soup. Taken together with evidence from intragastric infusion studies, these data indicate that volume effects will influence food intake only at relatively high volumes (Rolls & Roe, 2002) and if paired with a relatively-high energy density (Gray *et al.* 2002).

Variety as a distractor

Introducing sensorially-distinct foods, flavours and textures into a meal may serve to maintain interest in eating. If motivation to eat is enhanced by the presence of varied foods, the meal duration will be extended with a consequent increase in meal size. Sensory-specific satiety acts as a brake on intake and is associated with decreased liking for an eaten food, limiting selection and intake of that food whilst directing choice towards foods that differ from the eaten food in sensory characteristics. This process stimulates intake of a variety of different foods. Providing foods that vary along sensory and nutritional dimensions is likely to introduce sufficient novelty to sustain interest in eating and to promote intake, whereas consuming a single food enhances satiation processes, including the decline in the pleasantness of the taste and desire to eat that food.

Consumers who identify the change in pleasantness of the taste of a food as a primary reason for terminating intake tend to eat less than those who rely on gastric fill (Hetherington, 1996). This finding suggests that if the attention of the consumer is drawn to the change in pleasantness of the eaten food during a meal, this process will facilitate the development of satiation and will limit intake. Attention to what is eaten and memory for recent eating contributes to the regulation of intake (Higgs, 2002, 2005). Multiple attentional targets (whether food- or non-food-related) will delay satiation.

This prediction has been tested in two studies in which participants were asked to consume a snack of either popcorn or chocolate. In the first within-subjects experiment participants attended the laboratory on four occasions for a snack. On one occasion they simply ate their preferred flavour (salty or sweet) of popcorn *ad libitum* without interruption. In this control condition participants rated the pleasantness of their preferred flavour of popcorn, immediately before and after intake. During the other three experimental sessions participants consumed their preferred flavour of popcorn, rated its pleasantness before and after intake and, in addition, made ratings of pleasantness

and desire to eat the eaten food (same food) or a different uneaten food (either congruent or incongruent in flavour to the popcorn) at intervals of 1 min during the snack. Instructions to stop and rate the foods were delivered by audio-tape. Interrupting participants to taste and rate a different food during eating increases consumption of their snack by 13% in the congruent condition (where the other food shared similar sensory characteristics) and by 18% in the incongruent condition (where the other food differed in sensory characteristics) compared with intake when attention is specifically drawn to the taste of the eaten food. This same taste condition maximizes focus on the sensory properties of the popcorn, with the congruent and incongruent taste conditions appearing to disrupt this focus. When ratings of pleasantness of the eaten food are compared across conditions, pleasantness declines rapidly in the same condition but remains relatively high in the congruent and incongruent conditions. Thus, increased food intake during congruent and incongruent conditions may be related to the delay in satiation observed in these conditions.

In the second between-subjects experiment participants attended the laboratory on only one occasion. Men and women were allocated to either a food-focus or a food-distraction condition. In the food-focus condition the participants were given chocolate to consume as a snack and were interrupted at 1 min intervals during eating to rate pleasantness and desire to eat that food. In the food-distraction condition the participants were asked to make the same ratings of a different food (cheese crackers) provided alongside the chocolate. Again, by simply introducing a salty food during the consumption of a sweet snack the pleasantness of the snack remains relatively high compared with attending to this food alone during the snack. Introducing variety during an eating episode appears to delay the normal decline in pleasantness associated with sensory-specific satiety (Hetherington *et al.* 2006b). This finding could explain, in part, why variety increases energy intake.

Variety is likely to stimulate overconsumption through a variety of mechanisms including the process of salivary dishabituation (Epstein *et al.* 1992) and extending positive orosensory feedback during the meal (Hetherington *et al.* 2006b). Short-term experiments suggest only that overconsumption in response to variety occurs within a meal, but it is not clear whether variety is relevant to long-term energy balance. In a study of variety effects in the longer term Stubbs *et al.* (2001) have studied six lean and six overweight men during a 9 d period with a limited (five), medium (ten) or a high variety (fifteen) of foods offered. In this experiment participants were monitored within a residential environment and the composition of foods was controlled, having identical macronutrient composition and energy density. For all twelve men access to the high variety of foods was found to increase energy intake. Also, the lean men were found to gain weight with the high variety of foods compared with the medium and limited varieties, and the overweight men tended to lose weight during the study, losing least weight with the high variety of foods. Thus, providing *ad libitum* access to foods that differ in sensory attributes enhances energy intake and in

some cases produces excess intake and positive energy balance. This result is an important demonstration of how short-term experimental studies can identify a key determinant of energy intake in the laboratory that then translates well to the longer-term context of body-weight regulation. This study also shows very distinctly that not all individuals are equally susceptible to environmental manipulations.

Increasing pleasure during eating

Variety may enhance eating by its effects on habituation and the extension of positive orosensory feedback; however, it is unlikely that variety itself enhances intake. The previously described studies have all involved a variety of highly-palatable foods within a meal or over several days. The implication is that less-liked foods offered over many days or months may not maximize pleasure and therefore intake. In a series of studies conducted over many years by researchers at Natick, MA, USA on US army rations (Hirsch *et al.* 2005) reduced energy intake has been found repeatedly when soldiers receive a variety of ready-to-eat meals in the field compared with the same foods offered in cafeteria settings. A comparison of acceptance ratings between field and control conditions shows higher ratings in the field group but a consistently lower energy intake. However, in the field soldiers discard items they do not like, or trade them for foods they like, which serves to maintain acceptance at a relatively high level despite lowered energy intakes. Reduced energy intake probably reflects long-term monotony and relatively unfavourable situational factors associated with eating in the field. This 'real world' example demonstrates the limits of variety in enhancing food intake, the importance of providing frequent changes in menus to promote novelty and the strategies consumers use to maintain the pleasure they derive from food such as trading items.

Another obvious means to extend positive orosensory feedback is the manipulation of palatability. Maintaining the energy and nutrient content of foods whilst manipulating palatability is the only method of determining the relative importance of pleasure over other variables in guiding energy intake and whether changing palatability alone can affect weight regulation. In a series of experiments on rats using an 'electronic oesophagus', in which animals can determine the rate of infusion of nutrients directly into the stomach when ingesting a flavoured solution, Sclafani (2004) has demonstrated that improving the palatability of the flavoured solution increases both energy intake and weight gain.

In human subjects palatability of individual foods tends to be associated with high levels of energy density, independent of fat levels, and high taste pleasantness is associated with greater levels of energy intake (McCrory *et al.* 2006). However, since palatability co-varies with energy density, it is difficult to disentangle the relative impact of each factor on weight gain. However, if energy content is kept the same and foods are made more palatable, as in the rat model, then the relative effects of energy and palatability can be determined.

Yeomans *et al.* (2001) have investigated this approach by developing a palatable version of a test meal using the simple addition of oregano. This alteration in flavour is sufficient to promote greater food intake. It has been suggested that increasing the palatability of foods may reduce their satiating effects (Yeomans *et al.* 2001; Robinson *et al.* 2005). Thus, the efficacy of a high-energy fat or carbohydrate preload in reducing subsequent food intake has been shown to be influenced by whether the test meal is bland or palatable. Each of the high-energy preloads reduces intake of the bland meal but not the palatable meal (Yeomans *et al.* 2001). Providing infusions of 300 ml high-energy high-fat soup directly into the gastrointestinal tract fails to inhibit intake of a palatable test meal relative to a bland test meal (Robinson *et al.* 2005), although these differences are not replicated with the high-carbohydrate soup preload. This outcome suggests that palatability may stimulate eating despite post-ingestive signals associated with satiation, particularly when these signals are relatively weak, as they are for fat.

Flavours paired with high-energy infusions are less preferred than flavours paired with more-dilute nutrient infusions (Sclafani & Ackroff, 2004). Thus, there is no simple linear relationship between palatability and increased energy density in stimulating both food intake and weight gain. Nevertheless, in animals flavours paired with nutrients may come to be preferred and this preference can occur even in animals that have been previously fed to satiety on lab chow. Thus, manipulations of palatability may, under certain conditions, disrupt normal satiation processes (Yeomans *et al.* 2001) and override homeostatic mechanisms of energy balance (Sclafani, 2004). It remains to be seen whether the same can be applied to human subjects over the long term, since the complexity of learning the consequences of eating paired with the diversity of flavours available in the human diet precludes a straightforward comparison. However, the possibility that palatability may impair satiation, and that this process could contribute to overeating and weight gain is worthy of further consideration, particularly given the consumer's efforts to maximize the pleasantness of the eating experience and the palatability of the foods they choose.

Pleasure and alcohol

Alcoholic beverages are often consumed before and with food in order to heighten appetite and to enhance the pleasure derived from the meal. Alcohol has the capacity to influence energy intake and how substrates are utilized (Suter, 2005), thus alcohol is an interesting and important component of the diet for body-weight regulation. Energy derived from alcohol is additive to total energy intake, i.e. there is no apparent compensation for alcohol energy within a meal (Poppitt *et al.* 1996, 1998). Alcohol also stimulates short-term intake relative to consuming no alcohol (Yeomans *et al.* 1999, 2003; Hetherington *et al.* 2001). Thus, when alcohol is consumed within 1 h of eating there is no adjustment made in intake (additive effect) and it can increase the amount consumed relative to no alcohol (stimulatory effect). It is not clear whether these

effects are compensated by reduced intake and/or increased physical activity later in the day or on subsequent days. However, in the short term at least, there is a highly-reliable effect of alcohol on promoting energy intake (Yeomans, 2004).

Interestingly, when consumers have a variety of foods to select from, alcohol intake favours selection of high-fat palatable savoury foods (Caton *et al.* 2004). It is not known whether alcoholic drinks produce these effects as a function of enhancing pleasure or through learning and expectancy effects. For example, consumers may have long conditioning histories of pairing alcohol with specific types of foods; thus, choice is directed by previous learning or it could be that ingestion of alcohol promotes high-fat high-energy foods as a function of metabolic processes.

To investigate the role of palatability in the 'aperitif' effect of alcoholic beverages an experiment has been conducted on lean males (Caton *et al.* 2006). The objective was to test the effects of alcohol intake on the development of sensory-specific satiety, perceived palatability of foods and food intake. Thus, a comparison was made of the amount eaten from two versions (bland or flavoured) of the same food items (crackers and cheese) at lunch following either a preload with or without alcohol. The no-alcohol preloads consisted of 405 ml chilled lightly-carbonated white grape juice (867.3 kJ), with pure ethyl alcohol (96%, v/v) wiped around the rim to reduce expectancy effects. The alcohol preloads consisted of 375 ml carbonated white grape juice with the addition of 24 g (30 ml) ethyl alcohol (7.5% (v/v); 1508.6 kJ). Pleasantness ratings of the lunch foods were taken alongside a selection of sweet and savoury bland and flavoured foods before and after the drinks and again after the lunch.

It was found that bland foods are rated as less pleasant than flavoured foods; however, alcohol increases intake of both bland and flavoured versions of the lunch compared with intake following no alcohol. Alcohol has no selective effects on perceived palatability and does not affect the development of sensory-specific satiety. Thus, alcohol stimulates food intake despite differences in palatability. What are the implications of this robust stimulatory effect of alcohol on energy intake in the long term and on weight regulation?

Most studies of short-term food intake have not followed participants beyond a single meal or have relied on diet records for subsequent meal intake (Mattes, 1996; Westerterp-Plantenga & Verwegen, 1999). In contrast, Foltin *et al.* (1993) have measured accurately all foods and drinks consumed in a residential setting after dextrose- or ethanol-containing drinks. In this study energy from both beverages was found to be only partially compensated within a 24 h period, although energy compensation on the days after beverage intake was not calculated. It has been estimated that there is a 2 d lag in compensation (de Castro, 1998) and, therefore, any adjustments in intake should be followed for ≥ 2 d following alcohol. A recent study of lean men (Caton *et al.* 2007) has compared the intake of a two-course meal following no alcohol, 375 ml glass of red wine before lunch (aperitif) or 125 ml wine served with the first course and 200 ml wine served with the second course (co-ingestion). Energy intake for the

remainder of that day and the following 3 d was then measured using diet records. Total energy intake was found to decrease the day after the experiment in all conditions and again on day 4, regardless of alcohol intake. Thus, under these conditions at least, the men adjusted for overconsumption in the laboratory on days 2 and 4. It is possible that for these lean men sufficient adjustment for overeating has a protective effect on weight status. However, these results may differ in older or overweight participants.

There is considerable interest in the relationship between alcohol intake, adiposity and obesity (Wannamethee *et al.* 2005). Large-scale epidemiological surveys (Arif & Rohrer, 2005; Wannamethee *et al.* 2005) indicate that moderate social drinking is protective against overweight and obesity but that excessive or binge drinking (more than four drinks daily) is associated with a higher BMI (Arif & Rohrer, 2005) and with central adiposity (Wannamethee *et al.* 2005). Similarly, higher alcohol intakes are related to poorer diet quality (Breslow *et al.* 2006). However, even this apparently linear relationship masks the observation that the poorest diet quality is associated with the highest intakes of alcohol at the lowest frequencies. Thus, it is not simply the amount of alcohol consumed but the frequency and pattern of drinking as well as the amount consumed that determines its impact on dietary intake and potential to weight gain.

The variable response to alcohol ingestion and body-weight regulation is supported by laboratory investigations (Clevidence *et al.* 1995) that indicate that weight gain following alcohol is linked to individual differences. The particular case of alcohol highlights the importance of the contribution of this macronutrient to the diet, its effect on stimulating intake and on individual differences in the ability of consumers to adjust energy intake in response to both energy from alcohol and additional food energy in regulating body weight.

Characteristics of the food environment

Human food intake is influenced by social setting; thus, energy intake in the presence of friends or family can increase by between 40 and 70% compared with eating alone (Shide & Rolls, 1991; de Castro, 1990, 1991, 1994). Eating with friends and family encourages greater food intake both by extending the duration of the meal and by providing a more pleasant context in which to consume meals and snacks (Herman *et al.* 2003). Thus, for example, participants rated a test meal as more palatable when this meal was eaten with a group of others than when eating the same meal alone (Bellisle & Dalix, 2001). Meals eaten alone tend to be somewhat functional, tedious and short. In contrast, eating a meal with others is perceived as an important and enjoyable part of the cultural experience. Indeed, most important social and cultural events tend to revolve around social eating (Rozin, 2005). When consumers eat in groups of familiar others they expect the focus to be on food sharing and the time frame is likely to be much longer than that set aside for eating alone (Herman *et al.* 2003). Similarly, the sorts of foods provided

for a social function will differ markedly from those eaten during a solo meal (de Castro, 1994). The social, psychological and environmental factors contributing to social-facilitation effects are highly variable (Hetherington *et al.* 2006a). However, it could be that eating with others simply stimulates eating as a function of duration, with longer sessions increasing exposure to food cues and providing greater opportunities to eat (de Castro, 1990). It is not possible in most everyday social contexts to identify the relative importance of meal duration or the type of food offered in stimulating consumption.

Thus, social-facilitation effects have been studied in the laboratory so that foods offered can be controlled as well as the duration of the meal. Importantly, key features of the social context can also be manipulated, including the number of diners and their familiarity to the participant. A recent experiment (Hetherington *et al.* 2006a) has considered the possibility that social eating, like eating in the presence of any distraction, increases food intake partly as a function of drawing the consumer's attention away from the food eaten, thereby extending meal duration and amount consumed. Therefore, a comparison was made of intake when eating alone and intake when consumers watched television or had their meal in the presence of familiar or unfamiliar others. Since the focus of interest was in how consumers allocated their attention during the meal (eating, drinking, talking) all meals were videotaped and then coded. A buffet-style meal was offered for lunch to approximate the typical foods eaten during social occasions. The meal consisted of a variety of different foods, including energy-dense palatable foods (bread, cheese, green salad, coleslaw, crisps, cakes). It was predicted that social-facilitation effects would favour selection of the most energy-dense and palatable foods. Thus, the four meal sessions consisted of eating alone with no distractions, eating the same meal with the television switched on or eating with two same-gender friends or two same-gender strangers. Inviting same-gender diners is important since women eat differently in front of men, tending to eat less in order to appear feminine (Mori *et al.* 1987).

Under these conditions three key findings emerge: energy intake is higher when eating alone with the television switched on or when eating with friends; meal duration is longer when eating with others (friends or strangers) compared with eating alone; videotapes indicate that attention is largely allocated to the meal when eating alone, but to non-food cues in the other conditions. The finding that when eating alone in the presence of the television (14%) or when eating with friends (18%) energy intake is higher than when eating alone supports the findings of the previous studies. However, the magnitude of the social-facilitation effect is much less than would be predicted from free-living studies (Bellisle *et al.* 1999; de Castro, 1990, 1991, 1994). This disparity is probably a result of the constraints of the laboratory (limited variety, limited time frame) compared with spontaneous meals in the 'real world'. Nevertheless, the study shows a selective enhancement of sweet high-fat foods (by >50%) when eating with friends compared with eating alone, indicating that social facilitation favours particular foods (easy-to-eat highly-palatable high-energy snacks) typical of

social eating occasions. Such an observation has been reported by Clendenen *et al.* (1994) who have found that eating with friends specifically increases intake of cookies compared with intake when eating with strangers.

It is interesting to speculate on why social contexts may favour overconsumption of high-energy high-fat foods rather than, for example, low-energy-density foods such as salad. It could be ease of eating or the palatability of these foods; it could be that consumers match their eating to what others eat (Herman *et al.* 2005) or that when distracted it is more difficult to monitor and limit intake of foods that are typically restricted. Of course, all these factors are likely to play a role in the social facilitation effect.

Key to social facilitation is familiarity of the other diners (Shide & Rolls, 1991; de Castro, 1994), since eating with strangers fails to reliably increase intake. Eating with strangers may necessitate greater vigilance than eating with familiar others, since the consumer may self-monitor (impression management) and compare their own intake against what others eat (social norms). When unfamiliar women are paired for lunch to eat pizza, the amount eaten is highly matched between the pair (Herman *et al.* 2005), suggesting both high levels of self-monitoring and attention to what the other is eating.

The finding in the experiment (Hetherington *et al.* 2006a) that television viewing increases energy intake by about 14% of a similar magnitude of effect to that reported by Bellisle *et al.* (2004). Watching television and eating with friends share the common property of introducing competing pleasurable tasks during eating that distract attention away from processing food cues. Scrutiny of the videotapes of each session indicates that the amount of time spent looking away from the meal is highest when watching television, thus the programme engaged the participant's attention. On the other hand, during social eating much of the time is spent looking away from the meal, with 40% of the time spent talking. Thus, when less attention is paid to the meal the ability to self-monitor is reduced and may interfere with the development of normal satiation. However, the presence of distraction alone is not sufficient to increase food intake, since eating with strangers had the same effect on time spent looking away from the meal, and time spent talking had no impact on energy intake, in this condition.

Long-term energy balance: implicating situational factors in weight gain

Given the earlier observations, is there any evidence that watching television contributes to weight gain as well as increasing time spent being sedentary? Television viewing is associated with snacking, sedentary behaviour and obesity (Hancox *et al.* 2004; Viner & Cole, 2005). One study of adolescents (Van den Bulck & Van Mierlo, 2004) has estimated that, since many of them eat while watching television, 1 h of television viewing is associated with approximately 653 kJ additional energy intake, and another study (Viner & Cole, 2005) has shown that television viewing at the weekends at 5 years of age predicts obesity

at 30 years of age. Thus, television viewing reduces physical activity and provides an opportunity for unmonitored additional energy intake that may track well into later life.

What about eating in a social context; does it contribute to weight gain? One study of the effects of transition from living alone to living with a partner (Kemmer *et al.* 1998; Marshall & Anderson, 2002; Anderson *et al.* 2004) has examined differences in food choice, eating habits, energy intake and body weight. In this study twenty-two couples were followed during the 3 months before and up to 1 year after moving in together. It was found that social eating occasions increase after marriage or cohabitation as couples eat together more often and the number of occasions spent eating with the extended family and friends increases. Couples are more likely to include alcohol with meals and encourage each other to break dietary restrictions (Anderson *et al.* 2004). There is a shift in the kinds of foods eaten as well as a net increase in total energy intake. Overall, it was found that both men and women gain weight within the first year of moving in together (women 1.5 kg; men 1.7 kg). The short timescale of the study may limit extrapolation to a wider context; however, there is some evidence that marital status influences BMI (Ball & Crawford, 2005).

A 'real world' example of transition that incorporates many different changes in eating habits involves leaving home to go to college. In this transition college students are exposed to a wider variety of foods, they eat together in social groups, regularly drink alcohol and are perhaps more likely to eat while distracted than when eating at home. Several studies (Anderson *et al.* 2003; Levitsky *et al.* 2004; Lowe *et al.* 2006) have shown a reliable increase in body weight, known in the USA as the 'freshman 15'. This phenomenon is widely acknowledged anecdotally but few systematic studies have been conducted. One such study (Anderson *et al.* 2003) has monitored body weight in 135 first-year men and women over the first 14-week semester and a smaller subsample until the end of the first year. An overall gain in weight of 1.3 (range -3.6-+5.2) kg was found in the first semester, and in the subset of freshmen monitored until the end of the first year the net weight gain was 1.7 (range -6.2-+11.4) kg. These findings are of a similar magnitude to that found in the couples moving in together (Anderson *et al.* 2004), suggesting some shared experience in the transition process.

Another study (Levitsky *et al.* 2004) that has provided further support for this weight change has reported an average gain of 1.9 (range -5.9-+8.6) kg in the first semester. Using a self-report questionnaire to investigate predictors of weight gain it was found that the variance in the regression models is largely accounted for by eating at 'all-you-can-eat' dining halls, increased snacking and consumption of high-fat snacks. Clearly, situational factors play a profound role in determining how much and what types of food are selected by consumers, and at times of transition (going to college, living as a couple) these changes in eating are sufficient to promote weight gain. It is obvious, however, that not everyone who experiences this sort of transition gains weight. In each of these studies it was found that the majority of participants gain a modest amount of weight; however, some lose weight and others

stay the same. Obvious questions that arise are: what predicts susceptibility to these environmental factors promoting overconsumption and weight change and who is most likely to gain weight under these circumstances? To address these questions it is necessary to consider individual differences; however, it is clear that few studies examining situational cues to overeat have identified specific individual characteristics that identify those susceptible to weight gain.

Characteristics of the consumer

If consumers are aware of the tendency for small changes in their dietary intake to produce changes in body weight they may attempt to limit food intake. Restrained eating is the construct used to describe this type of behaviour, i.e. imposing cognitive limits on food intake for the purpose of maintaining or losing weight (for a review, see Herman & Polivy, 2005). In the case of the weight gain that occurs in the first year of college, it might reasonably be predicted that higher levels of restrained eating would result in less weight gain than in individuals with low levels of restraint. However, Lowe *et al.* (2006) have examined weight gain in sixty-nine female first-year students and have related this gain to various measures of dieting and restrained eating. It was found that cognitive restraint scores from validated questionnaires fail to predict weight change; however, women with a history of dieting and with a high level of weight suppression (difference between current and highest-ever weight) are most likely to gain weight during their first year. The average weight gain across the year was found to be 2.1 kg, with this gain being greater (+5 kg) in those currently attempting to diet compared with former dieters (+2.5 kg) and those who had never been on a weight-loss diet (+1.6 kg). Similarly, those students with the highest levels of weight suppression were found to gain more weight over the academic year than those with low weight suppression. Evidently, individuals with a tendency to gain weight, as indicated by high levels of weight suppression, are those most likely to be on a diet and most vulnerable to the situational factors that promote energy intake during their first year. However, it is curious that those claiming to be restricting food intake to lose weight are also those most likely to gain weight. This seeming paradox has been illustrated in a series of studies by Stice *et al.* (2004) in which those subjects who score high on restrained eating measures fail to restrict their food intake under a number of different circumstances: in a laboratory-based snack; a laboratory-based healthy meal; a fast-food restaurant; a university dormitory dining hall. In all these different settings it is reasonable to suppose that there would be an inverse relationship between dietary restraint and energy intake; however, this relationship is not observed. Highly-restrained individuals may be restrained for the very reason that they are highly susceptible to food cues and tend to overeat. There are numerous studies (Polivy & Herman, 1985; Stice *et al.* 1999) that indicate a strong relationship between dietary restriction and the tendency to binge eat. It is not always clear whether restraint is imposed to counter episodes of overeating or if

efforts to restrict food intake increase the likelihood of overeating.

Whatever the direction of causality, there seem to be some circumstances in which restraint is accentuated and the tendency to restrict is enhanced and other circumstances in which restraint is abandoned. For example, Bellisle & Dalix (2001) have demonstrated that when restrained eaters are asked to focus on the food they are eating a lower intake is produced than when eating while listening to an audiotape. There is a correlation between restraint score and the difference in intake between baseline and distraction. Focusing on food appears to accentuate restraint by producing similar intakes to the baseline condition, but distraction increases intake especially in those individuals with higher restraint scores.

When restrained eaters are faced with cues that remind them of their intention to restrict food intake restraint is heightened, but if attention is narrowed to other cues then this situation promotes disinhibited eating (Mann & Ward, 2004). Dietary restriction is an effortful activity that 'costs' the restrained eater (Green & Rogers, 1999). Thus, if restrained eaters are asked to perform a task with a high cognitive load during eating, this additional demand on attention may impair monitoring of food consumption and produces an increase in intake relative to a low-cognitive-load activity (Ward & Mann, 2000).

There is, therefore, no simple relationship between an individual's tendency to restrict food intake and their susceptibility to gain weight in situations that promote overconsumption. It is not clear what specific individual characteristics protect against the obesogenic environment, although it is the case that some individuals are extremely good at resisting even the most systematic attempts at overfeeding. For example, a study of overfeeding (Jebb *et al.* 2006) has been conducted in which six lean healthy men took all meals in a metabolic 'hotel' for a period of 17 weeks. Following a 21 d baseline there were three overfeeding phases interspersed by 7 d of free feeding. The men were required to eat +20, +40 and +60% energy requirements, which was achieved by increasing the energy density of the diet through increasing fat content systematically. As expected, the result was weight gain and, on average, a failure to compensate for overfeeding during the periods of free feeding. However, there was an attempt by at least two men to compensate during the 7 d *ad libitum* periods, although 7 d may be insufficient for this ability to be fully expressed, and perhaps a longer period of free feeding would have permitted compensation to occur.

Jebb *et al.* (2006) have demonstrated that individual differences will determine how much weight is gained during systematic overfeeding. Evidently, there are some individuals who are resistant to situational cues to overeat, even when overfeeding is forced. However, it is not obvious what these individual differences are and how they arise. Are susceptible individuals more motivated by food reward or more sensitive to the presence of food cues? Recent imaging studies (Beaver *et al.* 2006) suggest that there is a correlation between sensitivity to reward traits and brain activation in response to palatable food images. There are, therefore, individual differences in the response

to situational cues involving food, and these differences may play a role in susceptibility to overeating and weight gain in the long term.

Conclusions

It is relatively easy to promote overeating in response to diverse situational cues. Most individuals have a 'thrifty' genotype that confers a slight or strong disposition to lay down fat stores. However, there are important individual differences in response to these cues. Although the present review has emphasized those circumstances that promote overeating (variety, alcohol, social context, distraction), these effects are mostly observed in the short term. Where longer-term studies have been conducted, individual differences become more salient, with some individuals highly susceptible to situational cues that promote overeating and weight gain, and others who tend to resist these cues. It is not clear whether this susceptibility is learned or endowed.

The specific effect of different gene variants on behavioural and physical phenotype has recently been examined (Cecil *et al.* 2006). This research has identified children who carry gene variants that confer some protection from obesity (Cecil *et al.* 2005a), but has also found that situational factors such as socio-economic status profoundly influence the risk of developing overweight and obesity (Cecil *et al.* 2005b).

Given that excess body weight tracks into adulthood and that circumstances converge in adulthood to promote weight gain, it is important to characterize the behavioural phenotype of children who resist overeating as well as identifying the source of behaviours that facilitate overeating, such as eating in the absence of hunger (Birch *et al.* 2003; Faith *et al.* 2006). Much of human eating behaviour occurs outside of metabolic requirements; however, there is a particular need to identify circumstances that are 'high risk' and that promote overeating, as well as characteristics of 'high-risk' individuals who are predisposed either through genes or learning to overconsume. Thus, through identifying the psychobiological profile of those individuals who fail to respond to situational cues to overeat and who might be resistant to obesity it will be possible to provide clues about how to challenge the obesogenic environment and develop a behavioural model on which to base interventions to in order to manage cues to overeat.

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