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External cues challenging the internal appetite control system-overview and practical implications

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Abstract

Inadequate regulation of food intake plays an important role in the development of overweight and obesity, and is under the influence of both the internal appetite control system and external environmental cues. Especially in environments where food is overly available, external cues seem to override and/or undermine internal signals, which put severe challenges on the accurate regulation of food intake. By structuring these external cues around five different phases in the food consumption process this paper aims to provide an overview of the wide range of external cues that potentially facilitate or hamper internal signals and with that influence food intake. For each of the five phases of the food consumption process, meal initiation, meal planning, consumption phase, end of eating episode and time till next meal, the most relevant internal signals are discussed and it is explained how specific external cues exert their influence.

Keywords

Food environment; satiety; satiation; food intake; obesity

Introduction

Over the past decades, the prevalence of overweight and obesity has increased tremendously. In 2013, worldwide 36.9% of men and 38% of woman were overweight or obese (Body Mass Index > 25 kg/m^2) (Ng et al., 2014) Being overweight or obese can have serious health consequences, as high BMI is an important risk factor for cardiovascular diseases, different types of cancers and type 2 diabetes (Wang et al., 2011). At the most basic level, overweight is the result of an imbalance in energy intake and energy expenditure: over time more calories are consumed than energy is expended.

Adequate management of food intake is a crucial factor in the development and prevention of overweight. Such food intake management constitutes a complex process involving concious and unconscious decisions on when to start, what to eat, how much to consume and when to stop eating. To support adequate food intake management, ethe human body is equipped with a sophisticated physiological system that provides a variety of internal signals, resulting in subjective feelings of hunger and satiety. This appetite control system has proven to be highly important in human evolution and has improved survival through periods of unstable food environments where shortages were altered with abundance (Bellisari, 2008). In order to survive, ancestral hunter-gatherers had to seek out and eat as many high-density foods as possible. Throughout thousands of years, it is believed that humans adapted themselves genetically to this environment, which makes them predisposed to be highly responsive to external food cues (King, 2013).

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However, the current high prevalence of overweight and obesity suggests that the appetite control system may be less effective in situations where food is in abundance (Popkin et al., 2004). In today's "obesogenic" environment, highly palatable foods are easy accessible, affordable and widely promoted (Lake et al., 2006). This makes that the appetite control system is challenged and potentially overpowered by habits, routines and cues in the external environment as (additional) determinants of the regulation of food intake.

External cues related to food and the food consumption environment exert their effect on subjective feelings of hunger and satiety through psychological processes as an addition to the internal signals from physiological processes (Mela, 2006; van Kleef et al., 2012b). External, environmental cues as for example packaging and portion sizes and labelling, tend to be strong, salient and seductive, and are believed to undermine the process of self-regulation necesary to the accurate management of food intake (Wansink, 2010; Wansink et al., 2009). Thus, subjective feelings of hunger and satiety are under the joint control of internal physiological signals and signals from the food consumption environment. These two types of signals may be aligned in that external cues possibly enhance and strengthen internal signals of hunger and satiety, but in many instances external cues signaling when to start, what to eat, how much to consume and when to stop, may override the internal signals of "start and stop" any consumption event, potentially leading to overconsumption.

The two interrelated processes of satiation and satiety are crucial for accurate food intake management (Bellisle, 2008). Satiation, sometimes referred to as within-meal satiety (Benelam, 2009) is the process that leads to the termination of eating (Blundell et al., 2010). Satiety, sometimes referred to as between-meal satiation, is the feeling of fullness after a meal and serves as a signal for the timing and size of the next consumption moment (Benelam, 2009; Blundell et al., 2010). For human food consumption, with more or less structured eating occasions, satiety is the more strategic process in food intake management as food intake decisions are made in an anticipatory fashion. That is, how much to consume at any discrete consumption occasion to ensure that the next eating occasion can be reached comfortably without a lack of energy or unpleasant feelings of hunger that may undermine the self-control to resist temptations to (over-) consume in between.

Taking as a starting point that food intake management is under the joint control of internal signals and external cues, we review scientific evidence on how external cues can support or undermine an individuals' responsiveness to internal signals. In current paper, external cues are defined as all signals related to the food consumption environment that are not regarded as internal, physiological cues.

External cues can be independent of food, such as social interactions, accessiblity and atmoshperhics or food dependent, such as all factors referring to the way food is presented or provided (e.g. package, structure, flavour) (Wansink, 2004).

This overview is not intended to be exhaustive in the sense that we provide a total review of all relevant studies, but aims to provide an overview and illustration of the wide range of external cues that potentially facilitate or hamper internal signals and with that influence food intake.

While excellent reviews exist on the influence and potential mechanisms of external cues influencing food consumption (Larson et al., 2009; Wansink, 2004) and particular internal physiological mechanisms of appetite regulation (Arora et al., 2006) this paper shows how their separate and combined influence exerts itself across five different phases of the food consumption process.

To provide some background, we start by discussing the different elements of the appetite control system from the perspective of the satiety cascade framework. Then, key findings are classified from previous research on the effect of external cues on appetite control, according to five stages of the consumption sequence: meal initiation, meal planning, consumption phase, termination of consumption, and initiation of the next consumption episode. Finally, implications for public health policies aimed at adequate food intake management are discussed and directions for future research are identified.

Internal signals from the appetite control system

An influential theoretical framework outlining the various internal signals affecting feelings of satiety and satiation over time is the satiety cascade proposed by Blundell over 25 years ago (Blundell et al., 1987a), that has been further updated by Mela (Mela, 2006). The satiety cascade (see Figure 1) details out the sensory, cognitive, post-ingestive and post-absorptive influences on feelings of satiation and satiety over time.

Following the satiety cascade, the start of a consumption moment is determined by a combination of internal hunger signals and cognitive factors. Just after the start of a consumption episode and prior of any post-ingestive or post-absorptive signals, perceived quality of a meal (in terms of expectations, reward and pleasure) is an important factor in the development of satiation feelings.

When consumed food reaches the stomach, post-ingestive and post-absorptive processes take over and meal quantity becomes important. The increase in gastric volume, the ‘stomach stretch’ is communicated to the brain and gastrointestinal hormones are released (Benelam, 2009). In combination with the cognitive perceptions of the food and drink consumed, this makes that satiation is stimulated.

When nutrients are absorbed by the intestines, satiety signals are released from the digestive track signalling to neurons in the brain during the post-ingestive phase of the satiety cascade (Blundell et al., 1987b) and satiety hormones are released. On the long term, the stimulation of satiety is based on the availability of nutrients sensed by the hypothalamus. When deviations from normal adiposity levels are detected, insulin and leptin are mobilized to induce satiety (Berthoud, 2007).

- Insert figure 1 about here -

External cues challenging the internal system

It might be expected that, over time, the internal appetite control system leads to appropriate timing and portion sizes of meals to avoid uncomfortable feelings of hunger or satiety (Booth et al., 1976). But external cues from today’s food environment seem to override and/or undermine these internal signals and make it more difficult to regulate food intake at any stage of the consumption process (Figure 2). Food consumption is often regarded as a rational processes with well-reflected decisions on what to choose and how much to consume. But in reality many of these decisions are taken impulsively rather than deliberately. Dual processing theory states that human behaviour can be guided by two systems (Epstein, 1994; Kahneman, 2011; Sloman,

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1996). System 1 operates automatically and is highly impulsive. Affective reactions and learned associations play an important role. System 2 is reflective and has the ability to monitor behaviour generated by the impulsive system 1. The impulsive behaviour guided by system 1 makes that we are more susceptible for external cues in all stages of the food consumption process, as further discussed in this paper.

- Insert figure 2 about here -

Meal initiation

Meal initiation refers to the begin situation in which the first (mental) steps are taken to acquire and consume food. The subjective feeling of hunger provided by the appetite control system is an important signal for meal initiation. However, in some instances external cues and not internal hunger signals induce the start of a consumption episode. For meal initiation, the external cue "eating by the clock" and other eating habits are important influencers. Eating by the clock is a fixed pattern of meals and snacks during the day (e.g. 7.30 breakfast, 12.20 lunch, 18.00 dinner) that many people develop over the years and comply with, regardless of hunger and satiety feelings. The development of eating habits is an effective strategy to save up cognitive capacity for other tasks and decisions since food intake is a reoccurring activity during the day (Marteau et al., 2012). Eating habits are the result of conscious decisions that have evolved into automatic behaviour (van't Riet et al., 2011). It can therefore be assumed that, although habits can overrule internal signals, there is still some sort of relationship between eating habits and internal signals. For satisfactory daily food consumption it is important to find a delicate balance between avoiding unpleasant hunger feelings and preventing abnormal fullness. Through experience with the intake of food, people find this balance and learn the optimum timing between two consumption moments. Over time, the repetitive use of this interval becomes a habit that will be predictive for future meal initiation. These habits are often so strong that they manage to be predictive even in the absence of hunger feelings (van't Riet et al., 2011).

Food cues in the environment or cues that have become associated with food (e.g. the shop where you always purchase your lunch) can also initiate food consumption. For example, a food cue can be the sight or smell of a food product but can also be the visibility of foods in an advertisement on TV or in a magazine (Cornell et al., 1989). These food cues influence meal initiation by altering physiological responses via two distinct routes. Firstly, food cues in the environment can increase feelings of hunger (Schüssler et al., 2012). The sight and the smell of a food can activate 'Cephalic Phase Responses', these signals are initiated by the central nervous system and prepare the gastrointestinal tract for optimal processing of the expected nutrients (Smeets et al., 2010) and seem to stimulate the ingestion of large meals (Williams, 2010). In addition, as soon as food cues as the smell of freshly baked cookies or the sight of a chocolate bar are perceived, the stomach stimulates ghrelin secretion. Ghrelin is a neuropeptide that induces appetite of which the levels normally increase before meals and decrease after consumption. Perceiving a food cue thus actually increases hunger feelings. Secondly, at the same time, the sight and smell of foods affect the level of dopamine transmission in the brain (Volkow et al., 2011; Volkow et al., 2002). The neurotransmitter dopamine plays a major role in reward-driven learning. When consuming a food for the first time, the level of dopamine transmission in the brain is increased and causes a feeling of enjoyment. When exposed to the food more often, the dopamine response transfers onto cues that are associated with food reward, for example the sight or smell of the particular food. Already the smell of a food can induce a dopamine response in the brain and becomes a predictor of reward. This response increases the desire to consume the food, inhibits cravings and is associated with 'wanting' of a food instead of 'liking' the food (Finlayson et al., 2008; Finlayson et al., 2007; Mela, 2006; Volkow et al., 2011). When food cues similarly trigger hunger feelings and food 'wanting', it is easy to imagine that resisting food intake is extremely difficult. Especially when cognitive capacity is low, it is a challenge to resist attractive food temptations (Ruhm, 2012).

In addition, culturally determined social norms and traditions are important influencers of meal initiation. The way in which people share food is surrounded by socially and culturally defined norms, such as generosity and reciprocity (Robson et al., 2006). Sharing food is not solely about eating, it strengthens relationships, creates feelings of solidarity and bonding and stimulates interaction among members of a specific society (Belk, 2010; Turner et al., 2001). So when refusing a meal, not only the host might be offended this can also have a potential negative effect on future interactions and relationships (Power et al., 2009). Therefore most people will accept and initiate the meal, even when they just ate and are not at all hungry.

Meal planning

Once the intention to eat something is there, the meal planning process starts. Meal planning refers to the forethought given to activities and means required to consume food. This is not necessarily a deliberate process, reacting on ones impulses and grabbing an apple while passing a fruit bowl, can already be considered as meal planning. A suitable consumption volume is often already selected before the first bite and seems to be fairly resistant to modification over the course of a meal (Fay et al., 2011). Fay et al. (2011) show that 28% of their participants still cleaned their plate although they reported to be satiated. An important mechanism in the pre-meal planning process is being able to learn from previous ingestions. Through post ingestive learning, people learn to associate the physiological consequences of food intake with different sensory food cues. One of the possible physiological consequences of food intake is the experienced level of satiety after consumption. Booth (1972) formulated the term 'conditioned satiety' to describe the association between sensory aspects of a food, as a sweet taste or creaminess, and the internal feeling of fullness afterwards. With the help of those associations we build expectations and learn how much we need to eat to feel comfortably full. Bilman et al. (2010) show for example that consumers expect a relatively higher level of satiety from products that are perceived as fat, high in protein, having a savoury taste and are in one piece. These generated satiation and satiety expectations do not necessarily have to be accurate, hence the plate cleaning while feeling satiated. Recent research suggests that these expectations, affect meal-size selection before the start of a meal (Brunstrom, 2007; Brunstrom, 2011; Brunstrom et al., 2011; Brunstrom et al., 2008a; Brunstrom et al., 2009; Brunstrom et al., 2008b). Some external cues undermine this learning process of conditioned satiety by influencing norms, perceptions and expectations and with that affect the meal planning process.

Packaging and portion sizes undermine conditioned satiety by suggesting that the restaurant portion or the pre-packaged or served food presented is the normal amount to consume. These packaging and portion sizes set a norm for the appropriate amount to eat and therefore make pre-meal planning based on own experiences unnecessary. People tend to eat the main part of the food that is presented or served to them. Studies show that intake from different packaging and

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portion sizes mirrors the amount of food presented: more food is consumed from larger portions compared to smaller ones without a significant difference in feelings of fullness afterwards (Rolls et al., 2004; Rolls et al., 2006a, 2006b; Wansink, 2010). A recent review of 104 portion size studies showed that doubling of portion size leads to an average consumption increase of 35% (Zlatevska et al., 2014). The unit size of food (i.e. the number of units in which a portion of food is divided) also influences consumption as people tend to eat many foods in units (e.g. slices, pieces). Typically, people eat more when food is presented in larger compared to smaller units (Geier et al., 2006; van Kleef et al., 2014).

The serving behaviour of others affects the meal planning process in a similar manner. Participants in modelling studies tend to serve a similar amount (or somewhat less) than the confederate who has been instructed to eat a lot or a little (Herman et al., 2005). This shows that in these social situations people rather use norms set by others than their own experiences and expectations.

The amount of food selected during the meal planning process is also affected by the size of dinnerware, including plates, spoons, bowls and glasses. People tend to over serve when it comes to larger plates and bowls and under serve when confronted with smaller dinnerware. This effect can be explained by the Delboeuf illusion (Van Ittersum et al., 2012). This illusion illustrates that a same size circle (as food on a plate) appears smaller when surrounded by a slightly larger circle and with that biases serving size perceptions and consumption. Van Ittersum and Wansink (2012) suggest that using smaller plates leads to an decrease in food intake without affecting feelings of fullness after consumption. Various studies on the portion size effect show that larger portions typically do not lead participants to report increased feelings of fullness. This again suggests that hunger and satiety signals are easily overridden or ignored (Chandon et al., 2010; Ello-Martin et al., 2005; Kral et al., 2004; Rolls et al., 2004; van Kleef et al., 2013).

Labelling and packaging cues can influence the amount of food selected during the meal planning process by altering product expectations that have been built through conditioned satiety. Low fat, organic and fair trade claims on packaging make that consumers expect a healthier food product than it actually is, the so called ‘health halo’ effect and therefore consume more (Schuldt et al., 2012; Schuldt et al., 2010; Wansink et al., 2006). Wansink and Chandon (2006) showed that low fat labels increased food intake independently of the type of snack, age of consumers, consumption setting, being an nutrition expert or not and whether people served themselves (Wansink et al., 2006). It might be that healthy food is perceived as less filling compared to other foods and therefore needs to be consumed in a larger amount to be equally satisfying (Finkelstein et al., 2010). Another explanation is that consumers' anticipated consumption guilt is reduced because the food is perceived to be healthier (Chandon, 2012). In addition to product claims, Piqueras-Fiszman & Spence (2012) showed that also the weight of a package is a subtle cue to influence satiety expectations. Products in heavier containers are expected to be more satiating and dense, both before and after tasting the food, compared to the same content presented in a visually identical but lighter containers.

Consumption phase

An important process in meal termination that develops during the course of eating is satiation. In this phase of food consumption, a food’s sensory features make that the body signals nutrient intake and with that increase feelings of satiation. An internal mechanism that stimulates the development of satiation feelings is sensory specific satiety: the decrease in pleasantness of the food that has been consumed generalizing to other foods that would deliver similar sensory features, such as taste or textures (Hetherington, 1996; Rolls, 1986; Snoek et al., 2004). Meal variety is an external cue that has the potential to overrule the process of sensory specific satiety. Meals that offer more variety in sensory features have less effect on the decrease in pleasantness to eat and therefore stimulate consumption (Brondel et al., 2009).

Recent studies show that the development of feelings of satiation through the mechanism of sensory specific satiety can also be accomplished without actual consumption (Larson et al., 2014; Morewedge et al., 2010). Morewedge at al. (2010) asked participants to imagine eating 3 or 30 M&M’s before actual consumption. Participants imagining the consumption of 30 M&M’s ate fewer M&M’s compared to participants imagining the consumption of 3 M&M’s. Larson et al. (2014) demonstrated that participants were more satiated of a particular food after showing them pictures of similar foods (i.e. all salty) with a task that emphasized the taste of that food. Both studies seem to rely on the same mechanism, the taste focus of the tasks make that the taste centre in the brain is stimulated and satiation for similar foods is affected.

A food’s texture is another influential external cue in the development of satiation feelings. Most probably, texture influences satiation through its effect on oral exposure time in the mouth. Taste receptors in the mouth inform the brain that food is being processed and nutrients enter the body. This makes that satiation feelings are stimulated. Because of a shorter oro-sensory exposure time, liquid substances lead to a lower satiation response and therefore later meal termination in comparison to solid foods (de Graaf, 2012).

Also a food's palatability influences the development of satiation feelings during the course of a meal. It has been argued (Berthoud, 2007; Erlanson-Albertsson, 2005) that when a 'standard food' is ingested, information on its energy content and taste are transmitted to the hypothalamus leading to the release of various satiety peptides and a decrease in appetite. But when a highly palatable food is consumed, taste sensing is different in comparison with a standard food. Information on the food is transmitted to the reward centre leading to an increased release from reward mediators as dopamine and serotonin. This reward centre has connections with appetite controlling neurons in the hypothalamus that induce hunger signals and suppress satiety signalling, which may lead to overeating and increased levels of adiposity (Berthoud, 2007; Erlanson-Albertsson, 2005). Several studies indeed show that more food is consumed when it is palatable compared to less palatable food with similar caloric content (De Graaf et al. 1999; Sørensen et al., 2003).

Some of the external cues as perceived variety and the palatability of a food activate physiological processes and with that influence feelings of hunger and satiation. Mainly these processes make it possible to ingest more food, hunger feelings are activated and/or feelings of satiation and satiety are repressed. Both neural and hormonal processes seem to be involved (Berthoud, 2007, 2012).

End of consumption episode

Towards the end of a consumption episode, the developed feelings of satiation lead to meal termination. Although bodily signals might inform the decision to stop eating, the actual decision to end a consumption moment needs to be made actively. Some external cues extend this decision and drive food consumption beyond the point that internal satiation signals would suggest. A distraction during an eating episode is such a factor and seems to reduce the monitoring capacity (Higgs et al., 2009). The presence of others (Herman, 2015; De Castro et al., 2000a; 200b), TV viewing or playing a computer game during consumption makes that less attention is paid to the meal that is therefore not encoded properly in memory (Higgs et al., 2009). Distractions also make a person less perceptive of internal satiation signals, which lead to a longer meal duration and increases intake (Conger et al., 1980; Goldman et al., 1991; Hermans et al., 2008; Hermans et al., 2012).

Similarly, atmospherics (e.g. music, lightning) during consumption influence food intake. Preferred or soft music and dimmed lightening encourage a slower rate of eating and longer meal duration. The pleasant ambience and the fact that leftover foods are available for a longer period of time make that it is more difficult to actively stop the consumption moment (Caldwell et al., 2002; Wansink, 2004; Wansink et al., 2012). Also packaging and portion sizes have the potential to drive food consumption beyond the point internal signals would suggest. The so called ‘completion compulsion’ makes that plates are cleaned and packages are emptied even when feelings of fullness would indicate to stop eating (Fay et al., 2011; Wansink, 2010).

Time till next meal

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The time till the next eating occasion is largely determined by the presence or absence of satiety feelings. Most probably, these satiety feelings have a physiological and a cognitive component. At the end of a consumption moment, when nutrients are absorbed by the intestines, satiety signals are released from the digestive track signalling to neurons in the brain in the post-ingestive phase of the satiety cascade (Blundell et al., 1987b) and satiety hormones are released. For the cognitive influence on satiety expectations and the timing and size of next meal it matters whether a person perceives an eating occasion as a snack or as meal (Pliner et al., 2007; Wadhera et al., 2012; Wansink et al., 2010).

Furthermore, satiety feelings can be influenced by labelling and packaging cues through altering satiety expectations. Both early work from Wooley (1972) and a more recent study from Crum and colleagues(2011) showed that beliefs and expectations can be important influencers in the process of satiety development and meal termination. Wooley (1972) found that people tend to report feelings of hunger and fullness in accordance with their beliefs on what they ate rather than the actual caloric content. Participants' food intake was reduced and feelings of fullness 20 minutes after consuming a meal were increased when the test food was positioned as ‘high calorie’. Crum et al. (2011) extended these findings by measuring the level of the satiety hormone ghrelin in response to the intake of differently labelled milkshakes. They showed that the level of ghrelin had a steeper decline when a milkshake was labelled as ‘indulgent’ than when the same milkshake was labelled as ‘sensible’, indicating that participants' internal feelings of satiety were in line with what they believed they were consuming. This finding indicates that the perception of what has been eaten not only has a cognitive effect but also mediates internal physiological processes. In addition, the proper encoding of a meal is important for the timing of the next meal. Rozin and colleagues (1998) showed that two amnesic patients, who most of the time were not able to remember what happened a minute ago, easily consumed three meals in a short time frame without a change in satiation feelings. This study emphasises the importance of the cognitive component in food consumption.

When hunger feelings return or habits, food visibility or social norms indicate that it is time to eat, a new consumption episode starts.

Conclusion and practical implications

Over the past years, an increasing number of studies have been dedicated towards the influence of external cues from the environment on food consumption. As a result, a wide range of cues has been identified and slowly the dominant physiological view towards food consumption and satiety has been complemented by a broader psychological perspective. Already in 1984, Herman & Polivy (1984) emphasized the influence of external cues on eating behaviour and developed the boundary model for the regulation of eating. Following this boundary model, humans have two end states, hunger on the one end and satiety on the other end, where internal physiological signals are most influential. When in the end state of hunger, extreme hunger is experienced that urges to eat and when in the end state of satiety, unpleasant satiety feelings urge to stop eating. In between these two end states there is a zone of biological indifference where external cues exert their strongest influence on the internal signals to start or stop eating. As a result, consumers in affluent societies are seriously affected by cues in the direct environment in which food decisions take place. Increasingly, the understanding of the interaction between individual factors of satiety and external cues is seen as critical to the development of smart and

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effective strategies to reduce intake without comprising on feelings of satiety. We structure potential strategies around the phases of the food consumption process as outlined in this paper.

Especially when contemplating the start of a consumption episode (*meal initiation*), the availability of food in the direct environment can be crucial for the actual decision on whether to start eating or not and for the type of food selected (Wansink, 2004). Therefore the unavailability of (unhealthy) food in the environment can limit the influence of external cues on food intake. Possible strategies to influence the availability of foods are for example restricting the sale of food products at the counter of non-food stores or banning vending machines from schools and workplaces. However, a recent study (Taber et al., 2014) shows that banning vending machines from schools might have a counter effect when in the direct environment of the school, soda and fast food are easily available. So in order to be effective it is important that these types of measures are not carried out in isolation but should involve the complete local community. This can be a challenge, as most consumers do not like to be restricted in their options. A more subtle approach to limit the influence of external cues on intake is changing the accessibility of foods. A recently promoted concept that takes the accessibility of food products into account is nudging. Nudging refers to a type of intervention that interferes in the choice or eating environment of consumers, without banning certain products or telling them exactly what to do (Thaler et al., 2008). Building on insights of behavioural economics and psychology, the idea is to design choice environments in such a way that they encourage self-control and facilitate healthy behaviours. Moreover, nudging interventions are characterised by that they are inexpensive and easy to implement (Johnson et al., 2012). An example of a nudge that can have an influence on the start of a consumption episode is to reduce visibility and accessibility of tempting snacks near the checkout of a cafeteria (van Kleef et al., 2012a).

In the *meal planning phase*, one of the key factors contributing to overeating are portion sizes. Portion size has been the core element of many interventions. Besides portion size education to create awareness of portion control, altering portion sizes requirements in certain settings (e.g. schools, restaurants) or pricing strategies are also suggested (Steenhuis et al., 2009). For some foods, recommended serving sizes on food labels are acceptable interventions for consumers (Vermeer et al., 2010) and might be a reliable guide for portion size determination. In the meal planning phase it can also be helpful for consumers to use smaller plates when serving foods and to leave leftovers in the kitchen (Wansink, 2010).

In the *consumption phase*, a first possible approach would be to strengthen the signals from the internal physiological system to stimulate feelings of satiation and satiety. Both industry and the public sector have invested in the development of satiation- and satiety-enhancing food products. In these products, the food composition is changed to provide stronger physiological satiation and satiety signals (van Kleef et al., 2012b). This can for example be done by lowering the energy density of a food when adding water or air (Bell et al., 2003; Benelam, 2009; Rolls et al., 1999; Rolls et al., 2000; Rolls et al., 1998) or by increasing the chewiness and denseness of a product by adding certain types of fibres (Camire et al., 2007; de Graaf, 2005). For the development of satiation it can be beneficial to limit the variety of colours and tastes within a meal (Brondel et al., 2009).

Towards the *end of an eating episode*, signals from the internal physiological system could also be strengthened through mindful eating approaches. Marchiori & Papies (2014) showed that a mindfulness based intervention effectively reduced effects of hunger on unhealthy food consumption. And the other way around, van de Veer et al. (2015) showed that focussing on outer body appearance takes up resources needed for relying on physiological cues resulting in higher food intake. Being mindful when eating might affect the development of satiation during the consumption phase and possible affects the end of an eating episode. More research is needed to determine the full potential.

The different phases could also be targeted by approaches inspired by social eating norms. The perceived eating habits of others have shown to influence food intake. Studies in which consumers are exposed to eating-norm messages have shown promising results (Robinson et al., 2013). Campaigns could also aim to change social norms such that consumers follow the behaviours of others in that they believe that smaller portions or water instead of soft drinks are the norm.

Based on learning from previous ingestions we form expectations and use these expectations in the meal planning process. Different external cues have the potential to alter these expectations as, packaging and portion sizes, labelling and packaging suggestions and dinnerware, and with that influence how much someone eats. There is still much to learn on these underlying mechanisms of external cues and their interrelatedness. All our experiences related to food consumption are stored in the orbitofrontal cortex (Morrison et al., 2007). In this part of the brain, all sensory information as colour, shape, taste and flavour are linked to social context, time and place of food consumption. In turn this information is attached to the consequences of food intake as its rewarding value and the feeling of fullness after ingestion. This makes it possible to learn from food ingestion and allows the adaptation of intake in future consumption situations. Habits and social norms are external cues that result from this learning process.

All cues in both the food and the eating environment are psychologically processed with potential physiological impacts. The next challenge in this research area is to examine the reinforcement of expectations, the interaction between external and internal cues or the interaction of several external cues. Increasingly, studies show that physiological and psychological signals not only have a separate effect on food intake and feelings of hunger and satiety, they also interact in determining food consumption. Descriptions about the nature of a food product (e.g. labels) and the texture of a food (Chambers et al., 2013; Hogenkamp, 2014) have been shown to influence satiety expectations and consumption (Hogenkamp et al., 2013; Vadiveloo et al., 2013). Initial evidence even suggests that food labels influence physiological satiety processes (Crum et al., 2011; Veldhuizen et al., 2013). Optimal combinations of interacting internal and external cues with a possible influence on food consumption are still unclear. Future research could unravel those processes underlying the interaction between external cues and internal physiological responses. This knowledge could provide insights for the development of satiety enhancing food (packages) and interventions that help people eat less.

Together, mechanisms as hormonal and neural processes and learning and conditioning seem to have one common goal: improving chances of survival in scarce food environments, by encouraging the efficient intake of energy, energy storage and use (Davis et al., 2014). These

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mechanisms direct the food consumption process by providing information on our need for food intake, what we like to eat, where we can find it and how much we should consume of it. For an important part this works through the external cues that are present in the environment.

Important in this respect is that many external cues exert their influence without much awareness. In attempts to reduce overconsumption of food, for decades, an implicit assumption has been that consumers make these decisions mindfully. Educational efforts that operate through deliberate decision-making processes (e.g. nutrition labelling, information campaigns) have had limited impact (Chandon et al., 2010) but can potentially be reinforced by changes in the environment. There is a now a turn towards the environment in overweight and obesity prevention. Consequently, the strategic focus has shifted away from individual responsibility towards societal responsibility for ensuring a healthy environment.

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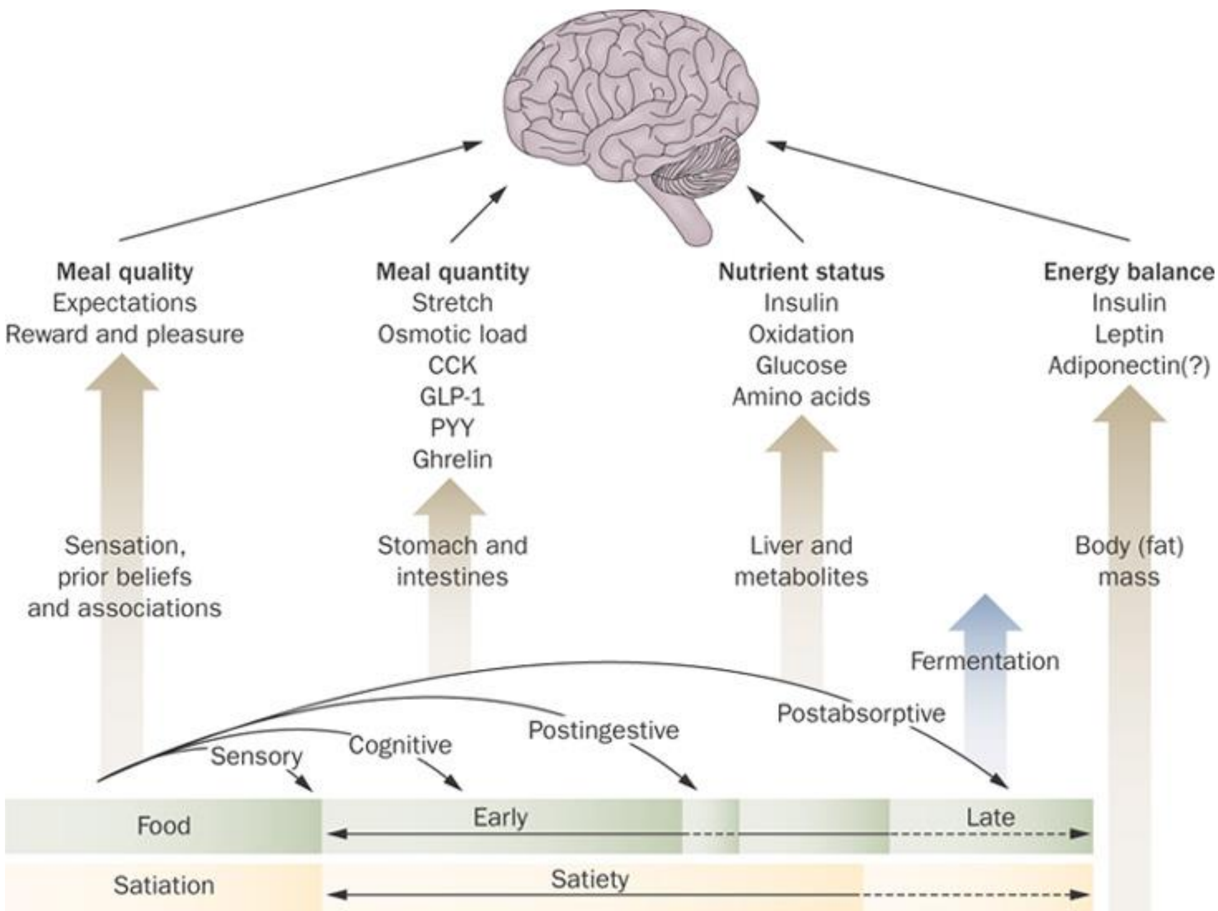

Figure 1. Satiety cascade from Blundell modified by Mela (Mela, 2006). Permission obtained from John Wiley and Sons, Blundell et al. (2010).

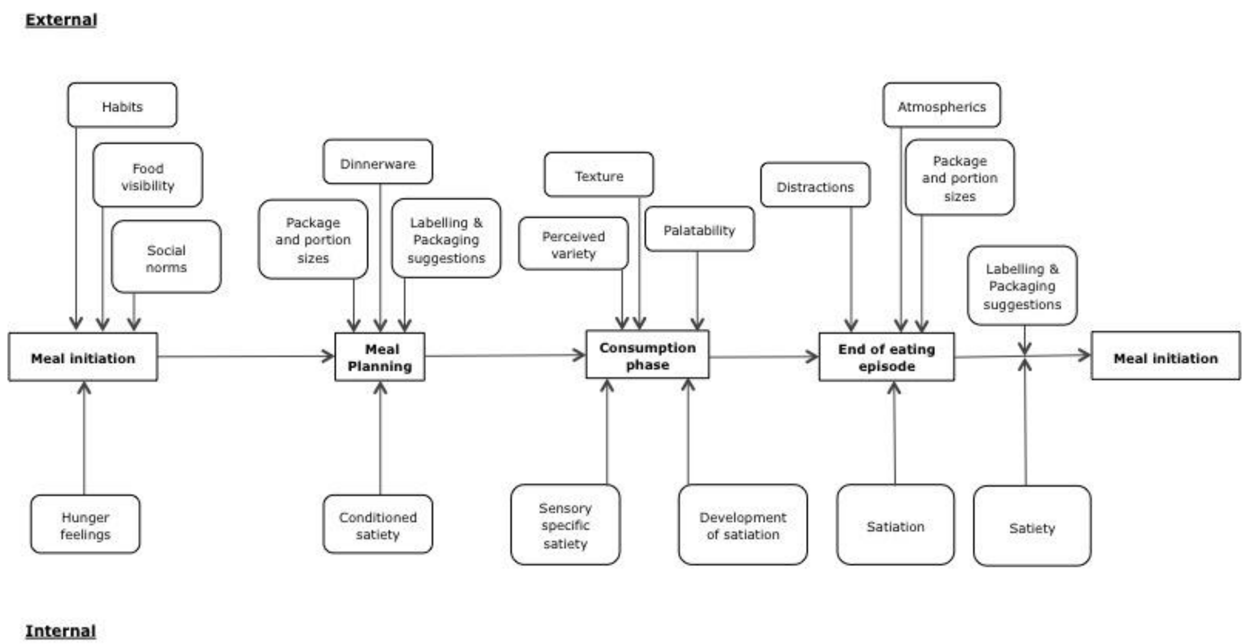

Figure 2. External cues challenging the internal appetite control