Dynamics of Food Choice and Sensory Specific Satiety

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ABSTRACT

Dynamics of food choice and sensory specific satiety

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Obesity is an important public health problem. It develops when energy intake exceeds energy expenditure on the long term. Energy intake depends on the foods one chooses to consume, and on the amount one consumes. The understanding of why some people do not make the right choices, despite intentions to do so, and of what drives overeating and the termination of consumption, will help to design intervention programs that aim at facilitating people to make healthy food choices and to consume sensible portions.

We investigated 1) which proportion of the participants would not act on their intention to choose a healthy snack, but choose an unhealthy snack instead, 2) differences between those who do and those who do not act on their healthy snack choice intentions, 3) which food properties affect the degree of sensory specific satiety (SSS) for food, which is an important implicit cue to regulate the amount consumed, and 4) whether the degree of sensory specific satiety predicts the long-term acceptance of foods.

The results show that, within the experimental context, about one out of four participants did not act on their stated healthy snack choice intention. Especially susceptible for not translating their healthy snack choice intention into action are males, lower educated people, non-dietary restraint people, and those who are not habituated to choosing healthy snacks. With regard to sensory specific satiety, high intensity foods tend to promote SSS, while complexity tends to attenuate the promoting effect of intensity on the development of SSS. Consumption of foods with small bites or small sips also promotes the development of SSS. The data do not support the idea that the degree of sensory specific satiety for a food predicts its long-term acceptance. Possibly, SSS is an implicit reaction to the food, while long-term acceptance also includes cognitions about the eating situation.

The results suggest that interventions that aim at facilitating people to actually making healthy food choices should target males and lower educated people, and focus on increasing their healthy snacking habit and self-control. To facilitate people to consume sensible portions, consumption of higher intensity foods, and consumption with small bites and sips should be encouraged.

CONTENTS

1

Introduction

The prevalence of overweight and obesity has increased dramatically over the last decades. In the Netherlands, the prevalence of overweight in adults has increased from 33% in 1980 to 50% in 2005. In the same period, the prevalence of obesity has increased from 5% to 11%. Overweight and obesity are associated with a high risk of various chronic diseases, particularly Type II Diabetes, high blood pressure, joint problems, sleep apnoea, and cardio-vascular diseases. Hence, the high prevalence of obesity has a major impact on the costs of health care (De Hollander, Hoeymans, Melse, Van Oers, & Polder, 2006). In order to improve the quality of life and to subdue the costs of health care, effective strategies to loose weight and to maintain a healthy body weight are required.

Weight gain is the result of a long-term positive energy balance, i.e. a long-term surplus of energy intake over energy expenditure. In the broadest sense, there are only two energy balance related behaviours: food (energy) intake and physical activity. A high energy intake therefore contributes to overweight and obesity. An obesogenic environment, in which the food supply is ample and large portions of energy-dense foods are readily available to consumers, can contribute to the overconsumption of calories, and thus play a role in the dysregulation of energy balance (Swinburn, Egger, & Raza, 1999). Making the right food choices in combination with consuming sensible portions could be a successful strategy to restore the energy balance and therefore to maintain a healthy body weight. However, people appear to perceive major difficulties when trying to adopt and maintain these behaviours in our current environment. Understanding such difficulties can help health professionals to develop strategies that facilitate people to loose weight or to prevent weight gain.

One factor that has been identified to contribute to the surplus of energy consumed in industrialized countries is the wide variety of foods to choose from. Studies have shown that choosing and consuming foods that are low in energy density contributes to the reduction of the daily energy intake (Rolls, Bell, & Thorwart, 1999; Poppitt & Prentice, 1996; Yao & Roberts, 2001). The explanation provided is that people tend to eat a similar weight of food during a meal and over a day, rather than a similar energy content. Low energy dense foods provide less energy per given weight of food than high energy dense foods. Choosing foods with a low energy density could thus play an important role in weight management. This has been confirmed in studies of the effect of fruits and vegetables on weight management, most of which found that the incorporation of fruits and vegetables in the diet was related to sustained weight loss (as reviewed by Rolls, Ello-Martin, & Carlton Tohill, 2004). In the present thesis, the terms 'healthy' and 'unhealthy' foods will be used. With 'healthy' foods, we refer to foods that are low in energy density. With 'unhealthy' foods we refer to all other foods.

One other factor that has been identified as an important influence on energy intake is the amount of food consumed, i.e. the portion size. Along with the increasing prevalence of overweight and obesity, the marketplace portion size of foods has increased substantially during the last decades, both in Europe (Matthiessen, Fagt, Biltoft-Jensen, Beck, & Ovesen, 2003) and in the USA (Young & Nestle, 2002). Controlled laboratory based experiments (Rolls, Morris, & Roe, 2002; Rolls, Roe, Meengs, Wall, 2004) as well as studies in the free-living environment (Diliberti, Bordi, Conklin, Roe, & Rolls, 2004; Kral, Meengs, Wall, Roe, Rolls, 2003) have demonstrated that increasing the amount of food served on a given eating occasion can lead to a substantial increase in energy intake of individuals. Public health efforts to address obesity should therefore focus on the need for people to timely terminate their food intake, and thus to consume sensible portions.

In this thesis we focus on the two issues that influence energy intake, i.e. making healthy food choices and consuming sensible portions. We first investigated inter-personal differences in the difficulty to make healthy food choices despite healthy intentions. Secondly, we examined properties of food that affect the development of sensory specific satiety for food. In this introduction we first describe why it may be difficult to choose healthy foods (i.e. foods that are low in energy-density), and why this may be more difficult for some people than for others. Then we describe how sensory specific satiety may limit the amount consumed of a chosen food. The importance of the (anticipated) reward derived from consumption in both processes is described. In the final paragraph of this chapter the research questions and the outline of the thesis are described.

THE HEALTHY CHOICE – THE DIFFICULT CHOICE?

People appear to have homogeneous conceptions of healthy eating, which are generally in line with the dietary guidelines (Lake, Hyland, Rugg-Gunn, Wood, Mathers, & Adamson, 2007). However, despite their knowledge about healthy eating, many people perceive difficulties to make healthy food choices. Understanding the underlying reasons of such difficulties requires insight in processes that play a role in food choice.

When given the choice between several options, an individual will prefer and therefore choose the option with the highest net present reward value. The underlying principle for this is that an individual usually behaves as to maximize the value of the outcome of a decision (Hammond, 1988). The net present reward value of an option is the combination of the reward derived from all elements that affect the choice for the option.

Food choice is a complex human behaviour, which is affected by many intrinsic as well as extrinsic elements. Among the extrinsic elements are environmental factors such as accessibility and availability, social factors such as the presence of others, cultural conditions such as appropriateness, and material factors such as the price of food and income (as reviewed by Shepherd, 1999). Cognitions and attitudes about the health value of foods have become increasingly important in making food choices (Wardle, Parmenter, & Waller, 2000). The most important intrinsic elements that affect food choice are sensory hedonic facors, i.e. enjoyment, and the current physiological need, i.e. feelings of hunger (Mela, 2001).

While, as denoted above, food choice is influenced by many elements, it often consists of a trade-off between future rewards associated with health benefits, and immediate rewards associated with enjoyment and the relief from hunger. Although it is well possible to derive both health benefits and enjoyment from consumption of a given food, it may be easier to think of alternatives which are regarded as healthy but not very enjoyable[1], or the other way around. Which of these alternatives is

[1] Compare for example an apple with a chocolate bar. Although an apple may be enjoyable for many individuals, most of us would prefer a chocolate bar over an apple if both options were equally healthy.

preferred, depends at first on the time until the choice comes into effect, and secondly on personality and situational factors (Figure 1.1).

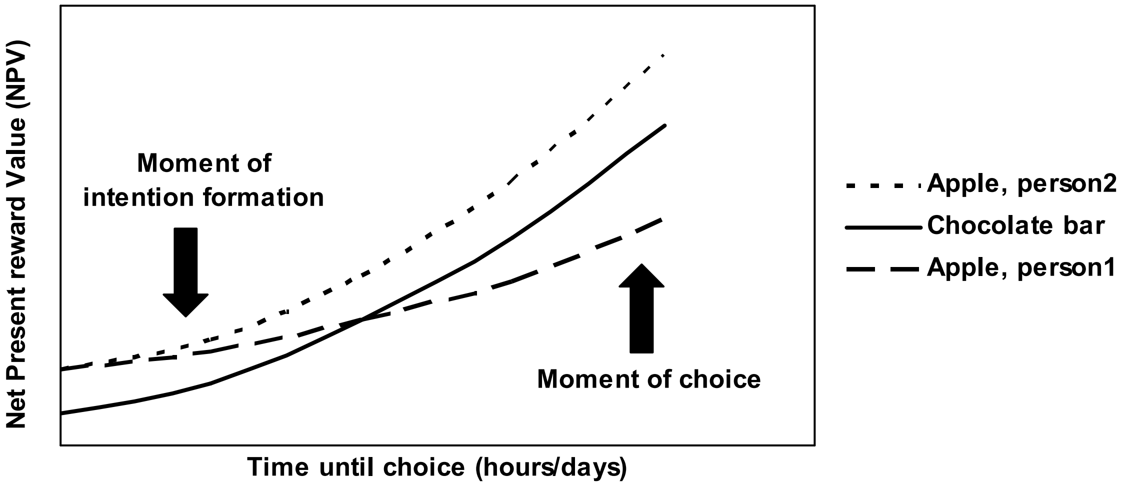

Figure 1.1: Hypothetical association between the net present reward value of healthy (e.g. apple) and unhealthy (e.g. chocolate bar) alternatives and the time until the choice is implemented. Personality, physiological, and environmental factors influence the reward value of a given alternative at each time point, and therefore the choice for a given alternative.

Time dependency of reward value of an alternative

The reward value of a given alternative to choose from may systematically change as a function of time relationship (Rachlin, 1989). Often, beliefs about the health benefits of an option seem to be more important some time before a food choice comes into effect, while a positive evaluation of sensory attributes of an option, i.e. enjoyment of the option, seems to be more important when the food choice draws near. This explains why an individual may prefer an apple over a chocolate bar some time before the choice comes into effect, while he/she acts with a different set of preferences when the time comes to make a choice, and chooses the chocolate bar after all (Figure 1.1).

Mathematically, this can be clarified as follows. The net present value (NPV) of a delayed reward, such as health, is diminished by the delay to its receipt. For example, for healthy people the prospect of getting ill due to an unhealthy lifestyle lies in the far future. Therefore, as long as people are healthy, the present value of health benefits is not as high as it would be when they were ill (S). The longer the delay (T) until the reward comes into effect, the more the net present reward value is diminished. For example, for an adolescent the prospect of getting ill due to an unhealthy lifestyle is further away than for middle-aged people. Therefore, the present reward of health benefits will generally be higher for middle-aged people. And the higher the impatience for a reward (*d*), the more its net present value is diminished by a given delay. That is, some people are less willing than others to wait for delayed rewards, such as health benefits, and choose for immediate rewards, such as unhealthy food. The association between the net present value (NPV) of a reward, the size of the reward (S), the length of the delay until the reward comes into effect (T), and the rate with which the reward is diminished by delay (*d*) can be described by the following function (Mazur, 1987):

$$\mathrm{NPV} = \frac{S}{1 + d\,T}$$

Some time before a food choice comes into effect, both enjoyment and health benefits are delayed, i.e. the net present value of both rewards is diminished by a factor T. The size (S) of the reward is probably higher for health benefits than for enjoyment. And although the delay until health benefits come into effect (T) is larger, the impatience for health benefits is probably lower (*d* smaller). That is, people are more willing to wait for health benefits than for enjoyment. Therefore, long before the choice comes into effect the net present value of options with health benefits, or in general of options with large delayed rewards, is likely to be higher. When the actual choice draws close, the reward of enjoyment immediately comes into effect (T=0 for enjoyment), and is thus not diminished. Therefore, at that time point the net present value of highly enjoyable options, or in general of options with small immediate rewards is likely to be higher (Ariely & Zakay, 2001).

Although the explanation just given may suggest that individuals consciously calculate and compare the reward values of the available alternatives before making their food choices, that is of course not always the case. In fact, the use of cognition for decision-making is usually time-dependent. Some time before a choice comes into effect people may allow themselves to think of the food choice they will make. At that time, explicit attitudes may better predict their preference for a given alternative than when the actual choice draws close. Then, the choice is likely to be made spontaneously, without much reflection, and therefore, implicit attitudes may better predict preference and choice for a given alternative (Wilson, Lindsey, & Schooler, 2000). This is especially the case for everyday consumer decisions, such as food choice (Bargh, 2002). The explicit attitudes of an individual are likely to be associated with cognitively valued delayed rewards, such as health outcomes, while implicit attitudes are often related to affectively valued immediate rewards, such as enjoyment of the behaviour (Shiv & Fedorkhin, 1999). Consequently, these two different attitudes may be conflicting (Wilson *et al.,* 2000). In support of this, Perugini (2005) showed that explicit attitudes predicted self-reported choices, while implicit attitudes predicted actual choices between fruits and candy bars. Self-reported choices may better reflect what an individual wants to choose, i.e. his/her intended choices, than his/her actual choices, as they are often subject to self-representation biases.

Although this phenomenon underlies the common observation that individuals often perceive difficulties in choosing healthy foods as opposed to choosing unhealthy alternatives, despite intentions to do so, it does not explain why some people do and some people do not act on their intentions. This may depend on differences in impulsivity (Nasser, Gluck, & Geliebter, 2004), sensitivity to immediate rewards (Borghans & Golsteyn, 2006; Davis, Patte, Levitan, Reid, Tweed, & Curtis, 2007), and impatience for delay of gratification (Bonato & Boland, 1983) between people. These differences are brought about by differences in personality, physiological, and situational factors (Figure 1.1). In the next paragraph we will describe the dependency of the reward value of an alternative on personality and physiological factors. We will not deal with the influence of situational factors, as this is beyond the topic of the present thesis.

Personality dependency of the reward value of an alternative

The one person is able to translate his/her healthy food choice intentions into action, while the other person is not. For the one person alternatives with health benefits provide the highest reward both when intentions are stated and when the choice is implemented, while for the other person alternatives with health benefits provide a higher reward only when intentions are stated, but when the choice is implemented more enjoyable options provide a higher reward (Borghans & Golsteyn, 2006). Or in other words, for the one person explicit positive attitudes towards healthy foods predict preference both when intentions are stated and when the choice is implemented, or convergent explicit and implicit attitudes predict preference at both time points, while for the other person divergent implicit attitudes dominate the positive explicit attitudes towards healthy foods when the choice is implemented.

A person with a strongly positive explicit health attitude may be particularly motivated to actually choose a healthy food. Therefore, his/her explicit health attitude is likely to override the possibly divergent implicit attitude and to predict preference both when intentions are stated and when the choice is implemented. This facilitates acting on his/her healthy intentions (Sheeran, Norman & Orbell, 1999).

The one person may consider a given alternative which provides health benefits, e.g. an apple, as highly enjoyable, while the other may not consider the apple as enjoyable. For the former person the explicit and implicit attitude towards choosing an apple are likely to be congruent, which facilitates acting on his/her stated intentions (Blundell, 2006).

Persons may differ in the degree of control they perceive over food intake, i.e. the degree of dietary restraint (Van Strien, Frijters, Bergers, & Defares, 1986). For individuals who have a high degree of control over food intake, along with a positive explicit attitude towards healthy foods, the impatience for health benefits is particularly low (Borghans & Golsteyn, 2006). Therefore cognitions about health benefits are likely to outweigh divergent implicit attitudes when the food choice is implemented (Hoffman, Rauch, & Gawronski, 2007), and thus healthy food choice intentions are likely to be acted on.

Differences in food choice habits may affect differences in the competency to enact one's intended choices (Aarts, Verplanken, & Van Knippenberg, 1998). For a person who regularly chooses healthy foods, the cognitive capacity required to control healthy food choices is limited and his/her healthy food choice intentions are enacted more or less automatically. This increases the positive affect and thus the immediate reward derived from the healthy choice (Winkielman & Cacioppo, 2001).

Some individuals may anticipate feelings of regret after nonperformance of the intended behaviour, while others do not anticipate such feelings. The anticipation of regret for choosing an unhealthy alternative acts as a strong explicit negative attitude towards unhealthy foods, which is likely to offset the influence of divergent implicit attitudes when the choice is implemented. This increases the likelihood of acting consistently with one's healthy food choice intentions (Abraham & Sheeran, 2003; Sheeran & Orbell, 1999).

Some individuals may better be able to control their emotions than others. In a person who is not able to control his/her emotions, the influence of implicit positive attitudes towards unhealthy options will fluctuate strongly as a function of mood (Garg, Wansink, & Inman, 2007). A low degree of control over one's emotions, i.e. a low self-regulation capacity, may therefore decrease the likelihood of adhering to an intended healthy diet (Fuhrmann & Kuhl, 1998).

Individuals may differ in their sensitivity to external cues when making food choices. For those who are sensitive to external cues, the presence of attractively looking and/or smelling foods will trigger positive implicit attitudes toward these foods to exert a strong influence on food choice (Schachter, 1968). Therefore, these individuals may be particularly susceptible to not acting on their healthy food choice intentions.

Dependency of the reward value of an alternative on the physiological need

Obviously, the physiological need of an individual, i.e. the degree of appetite, affects food choice. Already during infancy humans learn by associative conditioning to like energy-dense foods because they provide a satisfied feeling (Birch, 1992). When hungry, virtually the only goal of an individual is to get satiated. Therefore the accessibility of implicit positive attitudes towards unhealthy, energy-dense, options is very high, while the cognitive control to overrule these implicit attitudes is low. This enhances the susceptibility of hungry individuals not to act on stated healthy food choice intentions, compared to when satiated (Loewenstein, 1996).

Current research on the difficulty to enact healthy food choice intentions

Little is known about the proportion of individuals who are likely to fail to act upon their stated healthy food choice intentions, or about individual differences in the susceptibility to such a failure. Most studies that have been performed to understand food choice used a widely applied health behaviour model as the theoretical framework, such as the theory of reasoned action (Fishbein & Ajzen, 1975), the theory of planned behaviour (Ajzen, 1991), the model of interpersonal behaviour (Triandis, 1980), the protection motivation theory (Rogers, 1983), and the health belief model (Janz & Becker, 1984). These models predict intentions from a number of determinants, among which explicit attitudes. In turn, intentions are assumed to capture the motivational processes that influence behaviour (Ajzen, 1991). Most of the models above fail to address processes that occur after intention formation (Sutton, 1998).

Studies that applied those models showed that intentions are reasonably well associated with behaviour (see reviews by Armitage & Connor, 2001; Milne, Orbell, & Sheeran, 2002). However, these studies did not provide a reliable estimate of the consistency between food choice intentions and actual food choices, as they often used cross-sectional designs (simultaneous measurement of intention and behaviour), which are liable to self-presentational biases. Moreover, actual food choices were generally self-reported rather than observed. Self-report measures of behaviour may overestimate intention-behaviour associations, because of consistency or memory biases (Webb & Sheeran, 2006). Moreover, most studies did not attempt to provide an explanation for inter-personal differences in the discrepancy between intentions and actual choices.

Only few studies have investigated individual characteristics that may affect variations in the susceptibility to such a discrepancy. In studies with self-reported food choices as the outcome measure, emotion control (Fuhrmann & Kuhl, 1998), a positive explicit health attitude (Sheeran *et al.*, 1999), habitual healthy food choice (Brug, De Vet, De Nooijer, & Verplanken, 2006), and anticipated regret (Kellar & Abraham, 2005) have been shown to facilitate the enactment of healthy food choice intentions. In a study in which food choices were actually observed, however with several other limitations in the study design, appetite was shown to impede the enactment of healthy food choice intentions (Read & Van Leeuwen, 1998). The influence of other potentially important characteristics, such as dietary restraint, sensitivity to external cues, and enjoyment on the discrepancy between intentions and behaviour has not been directly tested for food choice decisions. Moreover, to our knowledge, no previous study investigated the possible influence of more characteristics simultaneously.

Additional studies that investigate the susceptibility to a failure to translate healthy food choice intentions into action are thus required. These studies should investigate whether differences in the personal and physiological factors described above can explain why some people are more susceptible than others to a discrepancy between their healthy intentions and actual food choices. The studies should be performed in a naturalistic setting, they should use a longitudinal design, i.e. measure intentions some time before actual food choices are measured, and the food choices should be observed rather than self-reported.

CONTROLLING FOOD INTAKE – THE ROLE OF SENSORY SPECIFIC SATIETY

As soon as a food has been chosen, many factors influence how much of the food is consumed. Facilitating people to consume sensible portions requires insight in factors that may promote overeating, and factors that could affect the termination of food intake. Many environmental factors that contribute to consumption of excessive amounts of food have been identified, among which portion size, lighting, distraction by TV viewing, socializing, and variety (as reviewed by Wansink, 2004). Although these environmental factors appear unrelated, they generally reduce the consumer’s attendance to sensory cues associated with ingestion of the food.

Attendance to oral sensory cues may be used to regulate the volume of intake (Poothullil, 2005). The hedonic evaluation of sensory cues during consumption determines the intrinsic immediate reward value derived from consumption. This depends on the level of stimulation that the food (i.e. the combination of its sensory characteristics) provides (Inman, 2001). It has been proposed that an individual strives to maintain an optimum level of stimulation (Zuckerman, 1979; McAlister, 1982). Therefore, when the sensory stimulation derived from consuming food is close to the individual's optimum, further eating is promoted. In the Arousal Theory, Berlyne (1970) distinguishes between situations in which the actual level of stimulation is below and above the individual's optimum, i.e. the desired level. When the actual level of stimulation is below the optimum, an individual will seek stimulation, by adding variety or novelty. In contrast, when the actual level is above the optimum, the individual avoids stimulation, by avoiding variety or novelty.

During consumption, the intrinsic reward value derived from consumption gradually declines. This phenomenon is referred to as *sensory specific satiety* (Rolls, Rolls, Rowe, & Sweeney, 1981). If sensory specific satiety occurs, one is specifically satiated to the sensory properties of the consumed food, but not completely satiated; the reward value of foods with other sensory characteristics remains unchanged (Hetherington, Rolls, & Burley, 1989).

An explanation for the phenomenon of sensory specific satiety may be that the optimal sensory stimulation declines during consumption. In other words, the consumer may want less and less stimulation of the sensory characteristics of the food, as their perception irritates more and more. This is supported by data of Rolls, Rolls, and Rowe (1983), which showed that when eating foods to satiety the pleasantness derived from consumption significantly declined, while the perceived intensity of the taste of the foods remained unchanged. When the optimal level of stimulation by the sensory characteristics of a food falls significantly below the perceived level, according to the Arousal Theory (Berlyne, 1970) the consumer responds by avoiding stimulation by the food. Stimulation is avoided by the termination of consumption of the food, while choosing foods with different sensory characteristics instead (Figure 1.2). In this way, sensory specific satiety contributes to variety seeking and therefore plays an important role in the consumption of a nutritionally balanced diet (Rolls, 1985), which is adaptive from an evolutionary perspective. On the other hand, sensory specific satiety is one way in which food intake is controlled (Hetherington, 1996).

Sensory specific satiety, i.e. the decline in intrinsic reward value derived from food consumption, is usually demonstrated by a decline in subjective acceptability judgments (e.g. liking, desire to eat) of a food as a result of immediate prior consumption of the food (Hetherington, 1996). Recently, fMRI investigations have shown that subjective declines in the reward derived from an ingested liquid food correlate with the decrease in responses of specific neurons in the orbitofrontal cortex to the sensory signals of the eaten food. Meanwhile, the neuronal responses to other foods, which have not been eaten to satiety, remain high (Kringelbach, O'Doherty, Rolls, & Andrews, 2003).

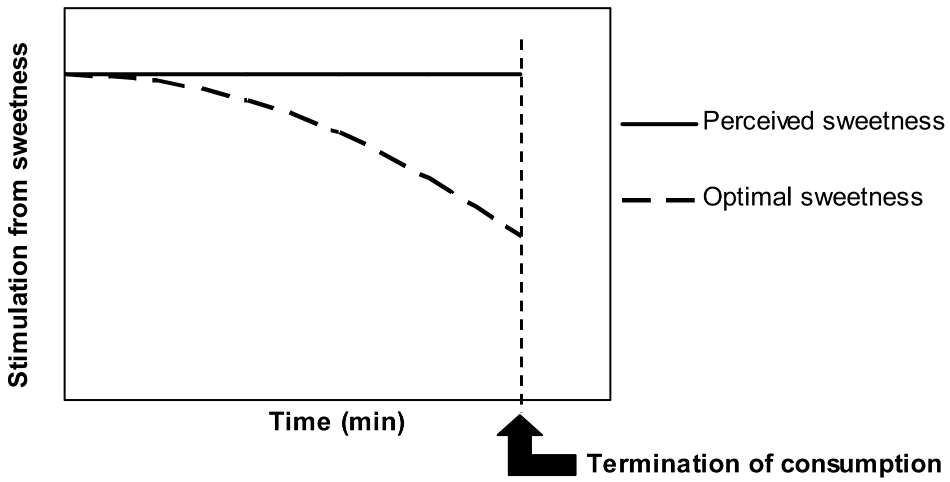

Figure 1.2: Hypothetical association between the decline in optimal level of stimulation by a given sensory characteristic (e.g. sweetness) below the perceived level, and the time until termination of consumption. As soon as the optimal level significantly declines below the perceived level, the individual will terminate consumption of foods with the given sensory characteristic (e.g. sweet foods).

Foods differ in the degree of sensory specific satiety they produce. That is, the reward value of some foods is sustained for a long time. Those foods can be eaten in large amounts. For other foods, the reward value derived from consumption rapidly declines, which leads to consumption of smaller amounts (Figure 1.3). This seems congruent with everyday experience: most people could drink many cups of tea without loosing the desire for another cup of tea, while consumption of coffee strongly reduces the desire for another cup of coffee only after two or three cups. Consumption of meals consisting of foods which produce only a low degree of sensory specific satiety may importantly contribute to the large portions people often consume. However, it is largely unknown what affects the decline in immediate reward derived from consumption, i.e. the degree of sensory specific satiety for a food.

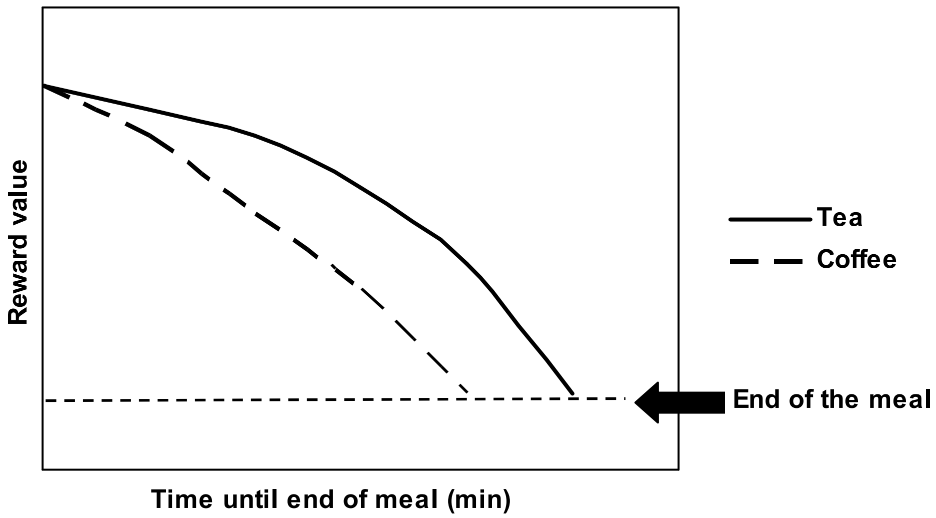

Figure 1.3: Hypothetical association between the decline in intrinsic immediate reward derived from consumption and the time until the end of the eating occasion. The rate of the decline in reward is an important factor in the regulation of the amount consumed, and differs between foods, e.g. between tea and coffee.

Properties that affect the decline in immediate reward derived from consumption

One property that has been suggested to affect the degree of sensory specific satiety is the variety of sensory characteristics of a food, i.e. its perceived complexity. It may be that consumption of complex foods attenuates the development of sensory specific satiety for a food. The fact that the sensory stimulation of complex foods is brought about by a variety of sensory characteristics may underlie this. When irritated with one of the sensory characteristics, the optimum level of stimulation provided by the other sensory characteristics may still be close to the perceived level of stimulation. This attenuates irritation with the food, i.e. with the combination of sensory characteristics, and therefore attenuates the decline in reward derived from consumption of the food. In support of this, Johnson and Vickers (1992) showed that within a meal the most complex food declined the least in liking. However, in a second study the results for complexity were not significant (Johnson & Vickers, 1992).

Consumption of foods with intense sensory characteristics may promote the development of sensory specific satiety. Intense foods may consist of a single dominant sensory characteristic, particularly when they are not complex. The more dominant and intense a sensory characteristic, the more rapid the optimal sensory stimulation may decline below the perceived sensory stimulation, i.e. the more rapid its perception may irritate. This promotes the decline in reward derived from consumption of the food. A few studies supported the suggestion of a positive association between the intensity of sensory characteristics of foods and the degree of sensory specific satiety they produced (Drewnowski, Grinker, & Hirsch, 1982; Maier, Vickers, & Inman, 2007). Likewise, Vickers and Holton (1998) demonstrated a negative association between the flavour intensity of iced tea and intake. Other studies could, however, not confirm the relationship between flavour intensity and sensory specific satiety (Rolls & Rolls, 1997; Guinard, Caussin, Campo Arribas, & Meier, 2002).

The oral work required to consume a food, i.e. the number of chews, may also affect the degree of sensory specific satiety for the food. Guinard and Brun (1998) demonstrated that sandwiches of hard baguettes produced more sensory specific satiety than sandwiches of soft white bread. For consumption of hard foods more chews are required as compared to soft foods. In a sensory specific satiety study, Johnson and Vickers (1992) demonstrated the smallest drop in liking for cola, which requires hardly any oral work, and the largest drop in liking for turkey, which requires quite a lot of chewing due to its stringy texture. Recently, Hetherington and Boyland (2007) showed that chewing sweet gum suppressed subsequent desire for a sweet snack, but not desire for a salty snack. These findings might point to a positive relationship between the oral work and the degree of sensory specific satiety.

Hence, chewing may promote the development of satiety during a meal (Sakata, 1995; Lavin, French, Ruxton, & Read, 2002). The proposed mechanism is that chewing enhances caloric-independent satiation through activation of neuronal histamine in the hypothalamus (Sakata, Yoshimatsu, & Kurokawa, 1997). However, a difference in chewing cannot explain the high satiety value of soups compared to other liquid foods (Mattes, 2005). One plausible explanation of the difference between soup and other liquids lies in the difference of consumption mode. Soup is consumed with a spoon while other liquids are usually drunk. When consumed with a spoon the bout-size of a liquid food is usually smaller than when drunk. This increases the length of oral sensory stimulation per consumption.

It may thus in fact be that the length of oral sensory stimulation itself, without necessarily affecting the degree of oral work, affects the degree of sensory specific satiety for a food. This hypothesis is supported by evidence that viscous drinkable foods provide higher satiety ratings than more liquid foods (shakes differing in viscosity: Mattes & Rothacker, 2001; yoghurt vs. fruit drink: Tsuchiya, Almiron-Roig, Lluch, Guyonnet, Drewnowski, 2006; chocolate milk drink vs. cola: Harper, James, Flint, & Astrup, 2007). It may be that a long oral sensory stimulation increases the intensity by which sensory characteristics of foods are perceived, which may enhance the degree of sensory specific satiety. However, it may also be that differences in cognitive impressions about the satiating power the different stimuli impart to consumers (Tournier & Louis-Sylvestre, 1991) explain the results of each of these studies.

Most previous studies found that the degree of sensory specific satiety for a food did not depend on the energy content of the food, neither in (semi)-solid foods (Rolls, Hetherington, & Burley, 1988; Rolls, Laster, & Summerfelt, 1989; Miller, Bell, Pelkman, Peters, & Rolls, 2000), nor in liquid foods (Bell, Roe, & Rolls, 2003). However, evidence supports that that the liking for specific foods may be reinforced by rewarding effects from consumption, such as positive post-ingestive consequences. For example, the high liking of sweet foods is partly due to caloric conditioning (Booth, 1985). Therefore, it is conceivable that energy providing foods and foods that do not provide energy could differentially affect sensory specific satiety. Supporting this idea, a recent study showed that intake of a glucose containing solution suppressed the neural expression in the hypothalamus, while an equally sweet aspartame solution did not (Smeets, De Graaf, Stafleu, Van Osch, & Van Der Grond, 2005).

The relationship between sensory specific satiety and long term acceptance

The degree of short-term sensory specific satiety for a food may also capture the long-term acceptance of the food. Both phenomena incorporate the decline in immediate reward value derived from the food by exposure to its sensory characteristics. In the case of sensory specific satiety, the decline in reward value may affect the termination of eating the food. In the case of long-term acceptance, the decline in reward value after the previous experience with the food may affect the anticipated reward value and therefore selection of the food. The rate of the decline in reward during consumption of a food may predict selection of the food over repeated consumption.

On the other hand, repeated consumption of a single food item may include cognitive involvement, i.e. boredom with the overall eating situation, in addition to a decline in reward derived from the sensory characteristics of the food (Zandstra, De Graaf, & Van Trijp, 2000). Moreover, a recent study (Levy, MacRae, & Köster, 2006) showed that exposure to stimuli that are slightly more complex than the individual's optimum causes an upward shift in the individual's optimum, and thus in preference for more complex stimuli, while it causes a decline in preference for simple stimuli. In that study, the shift in the individual's optimum already occurred after a single exposure. However, it may be that such a shift usually only occurs after repeated consumption, while the time frame within which sensory specific satiety takes place (i.e. within a meal) is too short for such a shift to come about.

Empirical tests of the association between sensory specific satiety and long-term acceptance show conflicting results. Vickers and Holton (1998) found that liking for strong iced tea decreased over repeated exposure, which was predicted by a low *ad libitum* consumption in a sensory specific satiety test. However, in a recent experiment, Chung and Vickers (2007) demonstrated that the decrease in acceptance of high sweet tea over repeated exposure was not predicted by a sensory specific satiety test.

In case both phenomena are comparable, foods that produce a high degree of sensory specific satiety may rapidly loose acceptance over repeated exposure, and will thus not be selected any more after some exposures. Whether the promotion of foods that produce a high degree of sensory specific satiety could be a successful strategy to reduce portion size and as such to maintain a healthy body weight, depends on whether the phenomena of sensory specific satiety and long-term acceptance are different or not.

Current research on properties that may influence the development of sensory specific satiety for a food

Although there are data that suggest that consumption of foods with a large variety of sensory characteristics, i.e. complex foods, may attenuate sensory specific satiety, while consumption of foods with an intense taste may accelerate sensory specific satiety, only little research is available on these topics. Therefore, further research is required to confirm these associations.

In the studies which suggested that the degree of oral work required to consume food is positively associated with the development of sensory specific satiety, foods that also differed in many other aspects were used. Therefore, the possibility that factors other than differences in oral work could explain the results cannot be excluded. To provide a conclusive test of this hypothesis studies are needed in which only the oral work needed to consume the foods is varied, while other aspects are controlled for.

Next, studies that proposed that it is not necessarily the oral work, but the length of oral sensory stimulation that accelerates the development of sensory specific satiety, used stimuli that may also have differed in expectations about the satiating power. Therefore, the latter could also account for the differences in satiety between the stimuli. Studies with stimuli that only affect the length of oral sensory stimulation, while all other aspects are identical, are required to conclusively confirm this hypothesis.

Although it has been suggested that a sensory characteristic that is usually paired with energy (e.g. sweetness) differentially affects neural signals when not paired with energy, it remains to be investigated how this may affect the decline in reward derived from consumption, and thus the degree of sensory specific satiety.

Current data on the comparability of the phenomena of sensory specific satiety for a food and acceptance over repeated exposure of the food are conflicting. Whether those two phenomena are comparable or not remains therefore to be investigated.

AIM OF THIS THESIS

The studies described in this thesis comprise two general aims. The first aim was to get more insight in differences between persons that may explain why some people are able to act on their healthy food choice intentions, while others are not. The second aim was to get more insight in properties that affect the degree of sensory specific satiety for a food. Sensory specific satiety is an important driver of the termination of intake.

OUTLINE OF THIS THESIS

First, two studies are described in which the proportion of those who fail to act upon their stated snack choice intentions, and inter-personal differences in the consistency between healthy snack choice intentions and actual choice, were investigated. The designs were longitudinal and snack choices were actually observed in a naturalistic setting rather than self-reported (Chapter 2 and 3). The study described in chapter 2 included the influence of demographic variables, appetite, explicit attitudes about health, dietary restraint, emotion control (as measured by emotional eating), sensitivity to external cues, habitual healthy and unhealthy snack use, and enjoyment of healthy and unhealthy snacks, on the consistency between intended and actual snack choice. The study described in chapter 3 also included the influences of explicit attitudes towards taste and anticipated regret. Moreover, the study design was slightly adapted in order to measure snack choice intentions and behaviour within a more realistic time-span, to more accurately measure appetite, and to minimize the influence of social desirability characteristics.

Chapter 4, 5, and 6 focus on properties that affect the degree of sensory specific satiety. Chapter 4 describes two studies that investigated the associations between the degree of intensity and complexity of soups and snacks and sensory specific satiety. Secondly, the studies aimed to validate sensory specific satiety as a rapid predictor of long-term acceptance. In the study described in chapter 5 the relationship between the degree of oral work and sensory specific satiety for snacks was investigated. The snacks were identical in macronutrient composition, energy density, and hedonic evaluation. The degree of oral work was varied by varying the snack size, and therefore the bite-size, and the degree of attention to consumption. Bite-size and attention to consumption may affect the degree of oral work, as data have shown that food is chewed less when consumed with large bites vs. smaller bites (Spiegel, 2000), and when distracted from attention to consumption by TV viewing (Blass, Anderson, Kirkorian, Pempek, Price, & Koleini, 2006). The study described in chapter 6 investigated the association between the length of oral sensory stimulation, without affecting the oral work, and sensory specific satiety. The length of oral sensory stimulation was varied by varying the sip size and the delivery rate of orangeade. The second aim was to confirm that energy content does not affect the degree of sensory specific satiety for sweet orangeades. In chapter 7, the findings of the previous chapters are discussed, conclusions are drawn, and implications of the findings for theory and practice are given.

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2

Discrepancy between snack choice intentions and behaviour

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Objective: To investigate dietary constructs that affect the discrepancy between intentioned and actual snack choice. **Design:** Participants indicated their intentioned snack choice from a set of 4 snacks (2 healthy, 2 unhealthy). One week later, they actually chose a snack from the same set. Within one week after the actual choice, they completed a questionnaire that evaluated several dietary constructs. **Setting:** Worksite cafeterias. **Participants:** Office employees in the Netherlands (*N=585*, 65% male, mean age 39.6 y (SD 9.2), 83% highly educated). **Main outcome measures:** Snack choice intentions and actual snack choices (healthy vs. unhealthy). Demographic and dietary constructs. **Analysis:** Student's T-tests, chi-square tests, and logistic regression [$p<0.05$]. **Results:** Forty-nine percent of the participants (*N=285*) intended to choose a healthy snack. Of this group, 27% (*N=78*) chose an unhealthy snack instead. Ninety-two percent (*N=276*) of the unhealthy intenders did indeed choose an unhealthy snack. None of the dietary constructs significantly predicted the failure to enact a healthy snack choice intention. **Conclusions and implications:** Although a substantial discrepancy between healthy intentions and actual snack choice was demonstrated, the evaluated constructs do not adequately measure the psychological process by which intention is converted into practice. Future studies are required to further investigate this process.

Keywords: Intention; Behaviour; Snacks; Food attitudes; Personality

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INTRODUCTION

Individuals who intend to change to a healthy diet often perceive difficulties in converting their intention into practice. Despite this, studies that applied the Theory of Planned Behaviour (TPB, Ajzen, 1985) to predict dietary behaviour found that a considerable proportion of the behaviour variance (18-39%) could be explained by the intention to perform the behaviour (Armitage & Conner, 1999; Povey, Conner, Sparks, James, & Shepherd, 2005; Brug, De Vet, De Nooijer, & Verplanken, 2006; Verbeke & Vackier, 2005; Verbeke & Pieniak, 2006; Lien, Lytle, & Komro, 2002). However, in all these studies, behaviour was self-reported, and in most of them (Armitage & Conner, 1999; Verbeke & Vackier, 2005; Verbeke & Pieniak, 2006; Lien *et al.,* 2002) intentions and behaviour were measured simultaneously. These two factors may have contributed to an overestimation of the consistency between intentions and actual dietary behaviour. A study that measured dietary behaviour 6 years after having measured intentions found that intentions predicted only 9% of the behaviour variance (Conner, Norman, & Bell, 2002).

The inconsistency between intentioned and actual health behaviour is frequently reported (Sheeran, 2002) and may result from the fact that intentions are usually under cognitive control (Gollwitzer, 1996) while actual choices are often made rather impulsively and even unconsciously (Wansink, & Sobal, 2007). When decisions are under cognitive control, the desirability of delayed rewards, such as healthy aging, is high. On the other hand, when decisions are under impulse control, the desirability of immediate rewards, such as enjoyment, is high (Ainslie, 1975). The inconsistency between intentioned and actual food choice may vary among individuals and among situations.

A strong positive attitude towards healthy eating, a high level of dietary restraint and a high normal use frequency of healthy foods could increase the healthy intention-behaviour consistency. A strong positive attitude towards healthy eating may enhance the healthy intention-behaviour consistency, as it reflects a high cognitive involvement with the healthiness of food choices, which has been shown to lead to decisions with delayed rewards (Cacioppo, Petty, Kao, & Rodriguez, 1986). Dietary restraint (as measured by the Dutch Eating Behaviour Questionnaire, DEBQ, Van Strien, Frijters, Bergers, & Defares, 1986) may enhance the healthy intention-behaviour consistency, as it negatively correlates to self-reported food intake (Westenhoefer, Broeckmann, Munch, & Pudel, 1994; Van Strien, Cleven, & Schippers, 2000). Dietary restraint is thus a measure of self-control. A high normal use frequency of healthy foods may enhance the healthy intention-behaviour consistency, as habitual behaviour is performed more or less automatically and therefore requires little effort (Bargh, 1997).

A hungry state at the time of actual choice, a high enjoyment of unhealthy foods and high levels of emotional and external eating behaviour could decrease the healthy intention-behaviour consistency. When people are hungry, virtually their only goal is to alleviate themselves from this state, which may make them 'forget' delayed rewards (Loewenstein, 1996). The possibility to choose highly enjoyable foods, which are often energy dense, may be a temptation that distracts individuals from enacting their intentions with delayed rewards. People who are sensitive to external eating cues, which reflects sensitivity to prompts such as seeing or smelling desired food (Schachter, 1971), or who are sensitive to emotional eating, which is a tendency to respond to arousal by excessive eating (Bruch, 1973), might likewise be tempted to deviate from their healthy intention when exposed to attractive unhealthy foods.

The present study was designed to investigate the influence of the dietary constructs cited above on the discrepancy between healthy intentions and behaviour in snack choice. More insight into constructs that affect this discrepancy may contribute to the development of new approaches that can foster long-term changes in eating behaviour and thereby reduce overweight.

DESCRIPTION OF THE STUDY

Study design

The study consisted of two choice tasks separated by 1 week. During the *intentioned* choice, participants indicated on a paper that listed 4 snacks (two healthy and two unhealthy snacks but not labeled as such), which they would choose if they had the choice. They were told that they would receive that particular snack one week later.

The choice was completed immediately after lunch, when participants were expected to be satiated. One week later, participants made an *actual* choice out of the same 4 snacks, which were displayed on trays. At the time of the actual choice, we emphasized that the participants could choose any snack, regardless of the snack choice that they had indicated a week before. The actual choice was completed either directly after lunch (*N=329*, 57%), or between 2:00 and 4:00 pm, when participants were presumed to be more hungry (*N=256*, 43%).

Within one week after the actual choice, participants completed a web-based questionnaire in which they were first asked demographic information. Next, their health attitude was assessed using the 'general health interest' subscale of the Health and Taste Attitude Scales (Roininen & Tuorila, 1998), and the extent of the participants' dietary restraint, emotional and external eating behaviour was measured by the DEBQ (Van Strien, *et al.*, 1986). As the classification of the scores on these three scales depends on an individual's gender and BMI, the scale scores, which were measured in 5 categories, were classified into 7 classes according to the norm tables of the DEBQ. These classes range from 'very low' to 'very high' (Van Strien, *et al.*, 1986). Use frequency of the snacks offered in the choice task was measured using six categories from 'never' to '5 times a week or more'. Pleasantness of the snacks was rated on a 9-point scale, anchored from 'not at all pleasant' to 'extremely pleasant'. For data-analysis, the pleasantness ratings of the two healthy snacks and the two unhealthy snacks, respectively, were averaged, as they did not significantly differ from one other. Reported use frequency of the healthy and unhealthy snacks, respectively, was classified into two categories: frequent users (use frequency of any of the (un)healthy snacks ≥ 1/wk) and non-frequent users (use frequency of both (un)healthy snacks < 1/wk). Subjects who completed the study were rewarded with a lottery ticket. The study was exempt from review by the Medical Ethical Committee of Wageningen University (The Netherlands).

Data analysis

Statistical analyses were performed using SPSS for Windows 12.0.1. (Microsoft Corporation, Chicago, IL; 2004). To compare the evaluated constructs between participants with a healthy and an unhealthy snack choice, given their intended choice (healthy or unhealthy), chi-square tests were conducted for the dichotomous constructs and unpaired Student's T-tests for the constructs that were measured with interval scales. To investigate whether the evaluated constructs would moderate the association between healthy intentions and behaviour, a logistic regression model was constructed. In this model, actual choice was the dependent variable while intentioned choice and the interactions between intentioned choice and each of the constructs were the independent variables (backward LR). When a p-value of 0.05 was used as the cut-off point for removing the non-significant constructs from the model, only intentioned choice was retained in the model. A p-value of 0.10 was also used as the cut-off point to assess any trends in the relationship among the constructs.

Products

Products were four snacks: apple, banana, molasses waffle (Kanjers®, Van der Breggen BV, The Netherlands) and a candy bar (Snickers®, Masterfoods, The Netherlands). The snacks were chosen on the basis of a pilot study questionnaire, which was performed in a comparable group of participants (*N=35*). All snacks that were selected for the main study were considered as pleasant, appropriate as a snack during work, convenient to consume, and were frequently consumed. The pilot study participants attributed to two of the selected snacks, the apple and the banana, a high rating of perceived healthiness, and to the other two, the molasses waffle and the candy bar, a low rating (mean difference ≥ 5.2 on a 9-point scale). On the basis of the healthiness ratings in the pilot study, the investigators classified the snacks as healthy (apple and banana) or unhealthy (molasses waffle and candy bar) for the purpose of data analysis. Although it is possible that the participants of the main study classified the snacks differently, the large discrepancy in perceived healthiness between the snacks in the pilot study predicts that most participants would classify the snacks the same way as the investigators did.

Participant descriptives

Participants were office employees who were recruited in their worksite cafeterias. Out of 1064 participants in the *intentioned* choice task, 621 participants also completed the *actual* choice task. Afterwards, these 621 participants were sent a web-based questionnaire, which was completed by 585 of them. Their data were used for statistical analyses. The participants had an average age of 39.6 y (SD 9.2), 65% were male, and 83% were highly educated (at least a high level secondary education). The average body mass index was 24.3 (SD 3.1).

Participants reported a reasonably high liking of all snacks offered in the main study. The mean pleasantness rating of the healthy snacks (average of banana and apple) was 6.8 (SD 1.5) on a 9-point scale, which was higher than the mean pleasantness rating of the unhealthy snacks (average of molasses waffle and snickers), which was 6.2 (SD 1.7) [p=0.01]. Fifty-five percent of the participants reported that they frequently consumed the healthy snacks (apple or banana ≥ 1/wk), while only 8% reported to be frequent consumers of the unhealthy snacks (candy bar or molasses waffle ≥ 1/wk). The mean health attitude of the participants was 4.6 (SD 1.0), measured on 7-point agreement scales. The mean dietary restraint score, was 5.3 (SD 1.5), the mean emotional eating score was 4.6 (SD 1.7), and the mean external eating score was 4.5 (SD 1.5). These means were calculated after the crude scores (measured in 5 categories) had been recoded into 7 classes.

OUTCOMES

Intention-behaviour consistency

About half (49%, N=285) of the participants intended to choose a healthy snack. However, more than 1 out of 4 of them (27%, N=78), chose an unhealthy snack instead (Figure 2.1). Despite this large proportion of changes in the unhealthy direction, the majority of participants who intended to choose a healthy snack actually chose a healthy snack (73%, N=207). Of the participants who intended to choose an unhealthy snack, only 8% (*N=24*) chose a healthy snack instead (Figure 2.1).

Participants (*N=585*, 100%)

Intentioned choice=Healthy (*N=285*, 49%)

Intentioned choice=Unhealthy (*N=300*, 51%)

	Actual choice= Healthy (*N=207*, 73%)	**Actual choice= Unhealthy** (*N=78*, 27%)	**Actual choice= Healthy** (*N=24*, 8%)	**Actual choice= Unhealthy** (*N=276*, 92%)
Gender (% female)	34	27	58	36*
Freq. use healthy snacks (≥1/wk(%))	62	69	65	43*
Freq. use unhealthy snacks (≥1/wk(%))	3	8	8	13
Age	41.2 (9.2)	41.5 (10.5)	35.9 (7.2)	38.0 (8.6)
BMI	24.6 (3.1)	24.6 (3.1)	23.4 (2.9)	24.1 (3.4)
Health attitude[a]	4.9 (0.9)	4.8 (1.0)	4.9 (1.2)	4.4 (0.9)*
Dietary restraint[b]	5.6 (1.3)	5.7 (1.2)	5.4 (1.1)	5.0 (1.4)
Emotional eating score[b]	4.4 (1.6)	4.8 (1.6)	4.4 (1.6)	4.6 (1.7)
External eating score[b]	4.3 (1.4)	4.2 (1.4)	4.7 (1.4)	4.7 (1.5)
Pleasantness healthy snacks[c]	7.2 (1.3)	7.2 (1.1)	6.8 (1.6)	6.3 (1.6)
Pleasantness unhealthy snacks[c]	5.7 (1.9)	6.1 (1.9)	5.8 (1.7)	6.6 (1.4)*

Figure 2.1: Distribution of the intentioned snack choices and of the actual choices, given the intentioned choices, among the participants, office employees in the Netherlands. The demographic and dietary constructs (% or means (SD)) for each of the four possible combinations of intentioned and actual choice are shown.

* Significantly different [$p<0.05$] from 'actual choice = healthy', in participants with 'intentioned choice = unhealthy'.

[a] Measured on 7-point agreement scales (left anchor = do not agree at all; right anchor = completely agree).

[b] Measured in 5 categories (left anchor = never; right anchor = very often), but recoded into 7 classes (1 = very low; 7 = very high).

[c] Measured on 9-point scales (left anchor = not at all pleasant; right anchor = extremely pleasant).

Constructs associated with the healthy intention-behaviour consistency

The demographic and the dietary constructs evaluated, as well as the proportion of hungry participants, were comparable between participants who enacted their healthy snack choice intention and those who changed to an unhealthy snack. This means that none of the constructs clearly distinguished between those who did and those who did not enact their healthy intention. Participants who enacted their unhealthy snack choice intention were less likely to be female, were less likely to be frequent consumers of the healthy snacks, had a lower health attitude, and considered the unhealthy snacks as more pleasant than participants who changed to a healthy snack (Figure 2.1).

Logistic regression analysis confirmed that none of the evaluated constructs significantly moderated the association between a healthy snack choice intention and actual choice. However, there was a non-significant trend for a high pleasantness of the unhealthy snacks [OR=0.9], a high reported consumption frequency of the unhealthy snacks [OR=0.5], and a high level of emotional eating [OR=0.8] to attenuate the healthy intention-behaviour consistency (Table 2.1).

DISCUSSION

In the present study a fairly large inconsistency was demonstrated between healthy snack choice intentions and actual snack choices. This confirms the disproportionate valuation of immediate rewards, which has been previously demonstrated (Liberman & Trope, 1998; Ariely & Zakay, 2001; Loewenstein & Prelec, 1992). Yet, participants who intended to choose a healthy snack far more often actually chose a healthy snack than participants who intended to choose an unhealthy snack.

None of the evaluated constructs significantly modified the healthy intention–behaviour consistency. This might be partly due to the fact that all constructs that were associated with healthy behaviour were also independently associated with a healthy intention. Moreover, some of the constructs were associated with each other [e.g. $r_{(\text{emotional eating-external eating})} = 0.4$]. These associations may have affected the significance of the constructs. Additionally, the variation in terms of the constructs evaluated was relatively small between participants, probably due to the convenience sample used. Most participants had similar jobs, which may have caused their similarity regarding many other features.

Table 2.1: Results of the logistic regression analysis (backward LR)[a] to predict actual choice in terms of intentioned choice, and the interaction terms between intentioned choice and each of the evaluated constructs. This was done to investigate whether the evaluated constructs increased the likelihood of a healthy actual choice, given a healthy intentioned choice.

Independent variable	*P*-value remove[b]	OR healthy choice[c]	95% CI[d]	R^2 (Nagelkerke)[e]
Intentioned choice[f]	0.05	55.6	22.1-139.7	0.51
Intentioned choice[f]	0.10	40.6	11.0-150.3	0.51
Intentioned choice * emotional eating[g]		0.8	0.7-1.0	
Intentioned choice * pleasantness unhealthy snacks[h]		0.9	0.8-1.0	
Intentioned choice * freq. use unhealthy snacks[i]		0.5	0.2-1.0	

[a] Variables entered in the model: intentioned choice, intentioned choice*gender, intentioned choice*age, intentioned choice*BMI, intentioned choice*health attitude, intentioned choice*dietary restraint, intentioned choice*emotional eating, intentioned choice*external eating, intentioned choice*pleasantness healthy snacks, intentioned choice*pleasantness unhealthy snacks, intentioned choice*frequent use healthy snacks, intentioned choice*frequent use unhealthy snacks.

[b] *P*-value that was used as the cut-off point for removing non-significant constructs from the model.

[c] OR=odds ratio for choosing a healthy snack.

[d] CI=confidence interval.

[e] R^2 is the proportion of variance of actual choice that is explained by the variables in the given model.

[f] Reference category = unhealthy snack.

[g] Measured in 5 categories (left anchor = never; right anchor = very often), but recoded into 7 classes (1 = very low; 7 = very high).

[h] Measured on 9-point scales (left anchor = not at all pleasant; right anchor = extremely pleasant).

[i] Reference category = use frequency of < 1/wk.

Although in the present study the relationships between the healthy intention-behaviour consistency and emotional eating, and high pleasantness and consumption frequency of unhealthy snacks were not significant, the trends are in the same direction as findings from previous studies that demonstrated that counterintentional past behaviour (Verplanken & Faes, 1999; Ouellette & Wood, 1998; Verplanken, Aarts, Van Knippenberg, & Moonen, 1998) and lack of emotional control (Kuhl, 1984) reduced the impact of intention on behaviour. Even though some of the evaluated dietary constructs distinguished between those who did and those who did not enact their unhealthy intention, the number of participants who intended to choose an unhealthy snack but chose a healthy snack instead was not large enough (*N=24*) to support significant differences between these two groups.

A clear strength of the present study was that food choices were actually observed instead of reported. Most studies relied on self-reports of food choice (Armitage & Conner, 1999; Povey *et al.,* 2005; Brug *et al.*, 2006; Verbeke & Vackier, 2005; Verbeke & Pieniak, 2006; Lien *et al.,* 2002; Conner *et al.,* 2002), which are liable to self-presentational biases (Budd, 1987). Another strength is the longitudinal design of our study, i.e. that the behaviour was measured some time after the measurement of intention, instead of cross-sectionally, as was done in most of the previous studies (Armitage & Conner, 1999; Verbeke & Pieniak, 2005; Verbeke & Vackier, 2006; Lien *et al.*, 2002). Cross-sectional studies cannot rule out the possibility that behaviour causes intention rather than the other way round.

The insignificance of hunger as a factor in the consistency between intention and behaviour may be explained by the fact that participants' hunger states were only inferred from the time after lunch, which may not have reflected their real hunger. We chose this research design because we wanted the tasks to be as effortless as possible for the participants; however, an individual measure of the hunger state may have provided more valid results.

In the present study there was only one actual choice event. It might thus well be that the participants acted differently during the particular choice occasion than they normally would have, as they might have considered receiving a free snack as a treat. However, the fact that the participants who chose the unhealthy snacks during the experiment also normally consumed these snacks more often than the participants who chose the healthy snacks, and vice versa, supports that single snack choices of individuals might at least give an indication of their regular snack choices.

The healthy intention – behaviour consistency found in the present study, although not too high, may have been overestimated by social desirability, i.e. that the participants felt obliged to actually choose the same snack as indicated a week earlier. We may have overcome this by just surprising the participants with our return and not telling them that we would return to actually distribute the snacks. Another possibility may have been to offer different healthy and unhealthy snacks at the two choice moments.

The time in between the intentioned and the actual choice, one week, was longer than it probably would be in real life for snack choices. Therefore, all kinds of other influences than perceived difficulty to enact the intentioned choice, such as the wish for variation or taste-change (Loewenstein & Prelec, 1992; Schultz, 1964), may account for the inconsistencies between the intentioned and actual choices.

Finally, as a convenience sample was used in the present study, the results cannot be generalized to other populations. However, the fact that the proportions of healthy and unhealthy intentions were comparable among the 443 employees who dropped out after the intentioned choice task (47% healthy intentions, 53% unhealthy intentions), suggests that the intentioned choices of the participants were at least representative for the population that they were drawn from.

IMPLICATIONS FOR RESEARCH AND PRACTICE

A substantial gap between healthy snack choice intentions and actual behaviour was demonstrated. Despite that, the results suggest that individuals who plan to make a healthy choice are more likely to do so than those who plan to make unhealthy choices. Because more than 50% of the population seems to have no intention at all of making a healthy choice, identifying tools by which this group can be motivated to choose a healthy snack is strongly needed.

The constructs evaluated do not adequately measure the psychological process by which intention is converted into practice. Future studies are required to further investigate this process. These studies should include emotional eating and measures of pleasantness and consumption frequency of unhealthy foods to better understand their significance in choice consistency. These investigations should study diverse samples (e.g. people from different socio-economic groups, education levels, ethnicities, and ages), should measure intentions and behaviour repeatedly, and should mimic real choice situations as much as possible.

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3

Predictors of the consistency between healthy snack choice intentions and actual behaviour

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The present study investigated the factors that affect the intention–behaviour consistency of healthy snack choices. Intended snack choice was assessed by asking participants (*N = 538*) to choose a snack on paper, out of 8 snacks (4 healthy, e.g. melon and gingerbread, and 4 unhealthy, e.g. crisps and chocolate). The next day participants chose one out of 8 different snacks for actual consumption. Participants completed a questionnaire about attitudes towards taste and health, habitual snack use, self-control, anticipated regret, and pleasantness of the snacks. Results showed that 24% of the participants with a healthy snack choice intention chose an unhealthy snack instead. Female gender, a high education level, a strong habitual healthy snack use, and a strong self-control increased the healthy intention–behaviour consistency. To facilitate healthy choices, interventions should target males and lower educated people, and focus on increasing their healthy snacking habit and self-control.

Keywords: Snack choice; Intention; Habit; Demographics; Self-control; Intention–behaviour consistency

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INTRODUCTION

Understanding the determinants of food choice and eating behaviour helps in the development of effective strategies to combat the growing obesity epidemic in the Western world. The intention to perform a behaviour is considered the most important determinant of that behaviour in the Theory of Planned Behaviour (TPB, Ajzen, 1985), which is one of the most widely used theories to study health behaviour (e.g. reviewed by Armitage & Conner, 2001; Godin & Kok, 1996). However, studies that applied the TPB to predict health behaviour found that intention explained between 19% and 38% of the variance in behaviour (as reviewed by Sutton, 1998), leaving a substantial amount of the variance unexplained. This means that there is often an inconsistency between intention and behaviour. In a recent study to assess eating behaviour in adolescents, no association was found between intention and healthy eating behaviour (Fila & Smith, 2006). The lack of association might result from the fact that food choice intentions result from deliberate processes, in which available alternatives, e.g. eating an apple or a piece of chocolate cake, are weighed against each other for their desirability (Gollwitzer, 1996), while actual food choices are often made impulsively and even unconsciously (Wansink & Sobal, 2007). For deliberate decisions, the desirability of long-term rewards, such as achieving a certain weight, is usually high. For impulsive decisions, the desirability of other, short-term rewards, such as enjoyment, is usually higher (Ariely & Zakay, 2001). The larger the temporal distance between the intention formation and the enactment of the target behaviour, the larger the incongruence between the desirability of the different rewards will be (Liberman & Trope, 1998).

The present study was designed to investigate the consistency between the intended and actual choice of in-between meal snacks and to examine the factors that affect this consistency. In the next paragraphs, we discuss some factors that are measured in the present study. We distinguish between attitudes related to the choice objects, behavioural factors, i.e. habitual behaviour and self-control, emotions aroused by the choice objects, i.e. anticipated regret and pleasure, and a physiological factor, i.e. hunger.

A strong positive attitude towards the behaviour (Sheeran, Norman, & Orbell, 1999) has been shown to enhance the intention–behaviour consistency of that particular behaviour. In two studies, Roininen *et al.* showed that a positive health attitude increases the intention to choose an apple (Roininen, Lätheenmäki, & Tuorila, 1999) and the actual choice of an apple, as compared to a chocolate bar (Roininen & Tuorila, 1999). Conversely, a strong positive taste attitude increases the likelihood of choosing a chocolate bar over an apple.

Habitual or past behaviour may also influence the intention–behaviour consistency. If the intention is congruent with past behaviour or habit, an intention–behaviour consistency is likely, while the opposite is true if the intention counteracts past behaviour (e.g. Armitage & Conner, 1999). This is because habitual behaviour has characteristics of automaticity (Bargh, 1997), which implies that initiation of the behaviour does not require conscious intent and therefore requires little effort.

A high level of self-control, or perceived behavioural control as it is called in attitude theory literature, also enhances the enactment of choices with long-term desirable characteristics, and therefore improves the intention–behaviour consistency (Schröder & Schwarzer, 2005). The level of self-control in food choice is determined by a combination of dietary restraint and externality. Dietary restraint refers to the intention to restrict and the actual restriction of food intake (Herman & Polivy, 1980) and may therefore increase the intention–behaviour consistency. Externality (Schachter, 1971) refers to choosing a food as an immediate response to seeing or smelling that food and may therefore decrease the intention–behaviour consistency.

As soon as individuals have formed an intention about particular target behaviour, they anticipate the outcome. The anticipation may include a comparison of a successfully implemented intention and a failed implementation. Envisaging a failed implementation may elicit the anticipation of regret (Perugini & Bagozzi, 2001; Perugini & Conner, 2000), which may increase the intention–behaviour consistency (Abraham & Sheeran, 2003; Richard, Van der Pligt, & De Vries, 1996).

Pleasantness of foods is usually considered the most important determinant of food choice (Drewnowski, 1997; Mela, 2001) as consumption of highly liked foods usually leads to enjoyment. Pleasantness may attenuate the intention–behaviour consistency as the possibility to choose highly pleasant foods, which are often energy dense, may be a temptation that distracts individuals from enacting their intention with long-term rewards.

The impact of the factors mentioned above on the intention–behaviour consistency may not be constant but may be influenced by an individual's internal state. For example, the level of self-control and the strength of the positive attitude towards healthy eating may diminish when an individual is hungry or thirsty. Feelings of hunger or thirst directly stimulate impulsive behaviours, which often oppose longer-term goals (Loewenstein, 1996), and as such may decrease the intention–behaviour consistency.

In the present study, attitudes towards health and taste, self-control (as measured by dietary restraint and external eating behaviour), habitual healthy snack use, anticipated regret for not choosing a healthy snack, pleasantness of healthy and unhealthy snacks, and hunger were investigated as factors that may influence the consistency between healthy snack choice intentions and actual behaviour.

METHODS

Participants

Participants were office employees of nine different companies in the Netherlands and were recruited in their worksite cafeterias. Out of the 1017 participants who were initially recruited and completed one choice task, 702 completed both choice tasks of the study. These 702 participants received a web-based ($N = 586$) or paper ($N = 114$) questionnaire, which 537 of them (46% male, mean age 38, range 18–63, 84% at least high level secondary education) completed. Their data were used for analyses. The proportion of participants who returned the questionnaire was similar for the two groups: paper survey participants (72%), and web-based survey participants (78%) [$p = 0.15$].

Products

Products, 16 snacks, were chosen as a result of a pilot study questionnaire, which was also performed in a worksite cafeteria (*N = 30*). In the pilot study questionnaire, participants rated 27 snacks in terms of perceived healthiness, pleasantness, appropriateness as an in-between meal snack and convenience to consume on 7-point agreement scales, and normal use frequency in five categories. Half of the selected snacks were considered as healthy (mean healthiness rating ≥ 4.2), and the other half as unhealthy (mean healthiness rating ≤ 2.1) [$p = 0.03$]. The selected snacks were generally considered as pleasant (mean pleasantness rating of all but one, i.e. carrot, above the 'neutral' midpoint of the scale) and convenient (mean convenience rating of all but two, i.e. carrot and melon, above the 'neutral' midpoint of the scale). The mean rating of appropriateness as an in-between meal snack was above the midpoint of the scale for eight of the selected snacks. The normal use frequency was not too high for some of the selected snacks. However, this is probably at least partly due to the wide variety of snacks to choose from.

The selected snacks were balanced for taste. Of the 'unhealthy' snacks, 4 were sweet (peanuts with a chocolate coating, candy bar, biscuit filled with almond paste, glazed biscuit), 2 savoury (cheese and sausage), and 2 salty (crisps and salted peanuts). Of the sweet snacks, 2 were chocolates (peanuts with a chocolate coating and a candy bar) and 2 were biscuits. Of the 'healthy' snacks, 2 were fruits (apple and melon), 2 were vegetables (carrot and cherry tomato), and 4 were biscuits (fruit biscuit, raisin biscuit, fruit bar, gingerbread). The pilot study ratings and the classification in terms of perceived healthiness (healthy vs. unhealthy) are listed in Table 3.1. The biscuit snacks that were classified as healthy on the basis of the pilot study also conformed to the criteria for preferred snacks on the basis of their saturated fat (<4 g/100 g) and fibre (>2 g/100 g) content for the Netherlands Nutrition Centre (Voedingscentrum, 2006). None of the snacks that were classified as unhealthy conformed to these criteria.

Table 3.1: Pilot study (*N=30*) attribute ratings (mean (SD)) of the snacks that were selected for the study.

Snack	Pleasant[a]	Healthy[a]	Conve-nient[a]	Appro-priate[a]	Use frequency (%>1*/mo.)	Healthi-ness category[b]	Similarity category[c]
Crisps	5.6 (2.2)	1.2 (0.6) [d]	4.5 (2.5)	3.0 (2.3)	47	U	SAV
Gingerbread	4.4 (2.1)	4.5 (2.0) [f]	5.2 (1.9)	4.7 (2.2)	17	H	WB
Apple	4.4 (1.9)	6.6 (0.9) [g]	4.6 (2.0)	4.8 (2.3)	37	H	FV
Carrot	3.8 (1.9)	6.5 (0.9) [g]	3.8 (2.2)	4.2 (2.4)	17	H	FV
Biscuit filled with almond paste	4.8 (2.0)	1.8 (1.2) [d]	4.8 (2.3)	3.2 (2.2)	13	U	SB
Melon	5.7 (1.6)	6.8 (0.9) [g]	3.6 (2.1)	5.0 (2.2)	23	H	FV
Fruit biscuit (Sultana®)	5.6 (1.5)	4.6 (1.8) [f]	5.9 (1.3)	5.0 (2.1)	47	H	WB
Glazed biscuit	4.0 (2.3)	1.5 (0.9) [d]	4.2 (2.2)	2.5 (1.8)	7	U	SB
Raisin biscuit (Evergreen®)	4.2 (2.2)	4.2 (1.7) [e]	4.7 (2.0)	4.8 (2.1)	20	H	WB
Candy bar (Snickers®)	5.0 (2.0)	1.6 (1.1) [d]	5.0 (1.9)	3.6 (2.3)	37	U	SB
Peanuts with chocolate coating (M&M®)	5.3 (1.9)	1.8 (1.2) [d]	4.7 (2.2)	3.6 (2.3)	20	U	SB
Fruit bar (Fruitkick®)	5.0 (2.1)	4.6 (2.0) [f]	4.6 (2.4)	4.6 (2.0)	16	H	WB
Cherry tomatoes	4.8 (2.1)	6.7 (1.0) [g]	4.0 (2.3)	4.1 (2.3)	14	H	FV
Salted peanuts	5.3 (1.8)	2.1 (1.3) [d]	4.8 (1.9)	2.9 (1.7)	11	U	SAV
Cheese	4.6 (1.9)	1.7 (1.0) [d]	4.6 (2.1)	2.9 (1.9)	10	U	SAV
Sausage (Bifi®)	4.8 (2.5)	1.6 (1.1) [d]	4.4 (2.0)	3.2 (2.2)	13	U	SAV

[a] Ratings were made on a 7-point agreement scale, anchored from 'completely disagree' on the left to 'completely agree' on the right, and 'neutral' at the midpoint.

[b] Classification in terms of healthiness, as made by the investigators, following the perceived healthiness ratings of the pilot study participants (H=healthy, U=unhealthy).

[c] Categorisation in terms of physical similarity, as made by the investigators (SAV=salty and savoury snacks, FV=fruit and vegetable snacks, WB=wheat biscuits, SB=sweet biscuits and chocolate).

[d–g] Within the column, means with different letters differ significantly from each other [$p < 0.05$].

In addition to a classification in terms of healthiness, the snacks were also categorised in terms of sensory and physical similarity into four categories, i.e. (1) fruits and vegetables (FV: apple, melon, carrot, or cherry tomato), (2) savoury and salty snacks (SAV: crisps, peanuts, cheese, or sausage), (3) wheat biscuits (WB: fruit biscuit, raisin biscuit, fruit bar, or gingerbread), and (4) sweet biscuits and chocolates (SB: candy bar, peanuts with chocolate coating, biscuit filled with almond paste, or glazed biscuit) (Table 3.1).

The fruit and vegetable snacks in the actual choice condition were precut in ready-to-eat pieces and offered in transparent containers in portions of about 100 g. The other snacks were offered in branded individual portion packages.

Study design and procedures

The study consisted of two choice tasks, separated by one day. During the *intended* choice task, participants indicated on paper which snack, out of 8 (4 healthy, 4 unhealthy, not labeled as such), they would choose if they had the choice. They were told that they would receive the chosen snack the next day. When participants returned the next day, 8 different snacks were displayed on trays. Again, 4 of them were healthy and 4 unhealthy (not labeled as such). Participants chose one of them. The snack they chose, we call the *actual choice*. The reason that the snacks offered at actual choice differed from those listed at intended choice was to prevent demand characteristics, i.e. that participants would feel forced to choose exactly the same snack that they had indicated to intend to choose the day before. Following both choices, participants indicated their feelings of hunger on a 9-point scale (left anchor: not at all hungry; right anchor: extremely hunger).

Both choice tasks were performed between 0 and 2 pm, either before or after lunch. Participants were told that the snack of their choice would be for consumption during the afternoon later that day. Moreover, they were instructed not to share the snack with colleagues, not to throw it away, and not to give it to someone else.

For each of the nine companies visited, the eight snacks listed during the intended choice and the eight displayed during the actual choice were randomly chosen from the 16 snacks selected from the pilot study under the following predefined conditions. Of the eight alternatives, 4 snacks were healthy and 4 unhealthy. One of the healthy snacks was a fruit, one a vegetable, and two were biscuits; one of the unhealthy snacks was salty, one savoury, and two were sweet. Of the sweet snacks, one was a biscuit, and the other a chocolate.

After completing the actual choice, participants filled in a paper or web-based questionnaire. The questionnaire measured demographic variables; health and taste attitudes (Roininen & Tuorila, 1999); self-control, measured by dietary restraint and external eating (Van Strien, Frijters, Bergers, & Defares, 1986); habitual snacking behaviour (Verplanken & Orbell, 2003); anticipated regret for not choosing a healthy snack (Abraham *et al.*, 1999); pleasantness (9-point scale); and normal use frequency of the snacks offered in the study (in five categories). For data-analysis, each individual's scale score of dietary restraint and external eating, measured in five categories, was classified into one of seven categories, according to the norm tables of the Dutch Eating Behaviour Questionnaire (DEBQ, Van Strien *et al.*, 1986), to correct for gender and BMI. The pleasantness ratings of the healthy and the unhealthy snacks, respectively, were averaged. Reported use frequency of the healthy and unhealthy snacks, respectively, was classified into two categories: frequent users (use frequency of any of the (un)healthy snacks ≥1ˣ/week) and non-frequent users (use frequency of all the (un)healthy snacks <1ˣ/week).

Data-analysis

Statistical analyses were performed using SPSS 12.0.1. Effects were considered statistically significant at a value of $p < 0.05$.

The participants' descriptives were compared by gender and by normal use of the healthy snacks (frequent vs. non-frequent users), using unpaired Student T-tests and Chi-square tests. Pearson's correlations were calculated between the variables measured at interval scale.

Chi-square tests and unpaired Student's T-tests were used to compare the measured variables among participants, according to their intended and actual choice (healthy vs. unhealthy). To test which variables would enhance the consistency between healthy intentions and behaviour, a stepwise logistic regression analysis was performed. At the first step, intended choice was entered. At the second step, the interactions between intended choice and each of the measured variables were added (backward logistic regression). A p-value of 0.05 was used as the cut-off point for removing the non-significant terms from the model. To compare the participants with a consistent choice and those with an inconsistent choice in terms of physical similarity, discriminant analyses were performed for each of the four intended choice categories (FV, WB, SB, and SAV) with the consistent and inconsistent choosers as the dependent variable and with the measured variables as the independent variables.

RESULTS

Participant descriptives

Table 3.2 shows the descriptives of the participants, most of whom were highly educated. Females had a stronger health attitude [$p < 0.001$], taste attitude [$p < 0.001$], and healthy snacking habit [$p < 0.001$], a higher anticipated regret for not choosing a healthy snack [$p < 0.001$], and a higher reported pleasantness [$p = 0.008$] and use frequency of the healthy snacks [$p = 0.008$] than males, while their reported use frequency of the unhealthy snacks was lower than of males [$p = 0.002$]. Frequent consumers of the healthy snacks had a stronger health attitude [$p < 0.001$], taste attitude [$p = 0.01$], and healthy snacking habit [$p < 0.001$], a higher level of dietary restraint [$p = 0.01$], and a higher rated pleasantness of the healthy snacks [$p < 0.001$] compared to non-frequent consumers.

Many of the variables measured correlated with each other (Table 3.3). For example, the participants' health attitude was positively associated with their level of dietary restraint, their healthy snacking habit, their anticipated regret for not choosing a healthy snack, and the rated pleasantness of the healthy snacks. Health attitude was negatively associated with the sensitivity to external eating and the rated pleasantness of the unhealthy snacks. Moreover, a healthy snacking habit was positively associated with dietary restraint, anticipated regret for not choosing a healthy snack and the rated pleasantness of the healthy snacks, while it was negatively associated with the rated pleasantness of the unhealthy snacks and the sensitivity to external eating.

Table 3.2: Participant descriptives (mean (SD) or %), overall, and separately per gender and per use frequency category of the healthy snacks.

	Overall (*N=537*)	Male (*N*=245)	Female (*N=292*)	Non-frequent healthy snack consumers (<%1*/wk, *N=111*)	Frequent healthy snack consumers (≥%1*/wk, *N=427*)
Gender (% female)	55			43	58
Age	37.8 (10.0)	40.4 (9.9)	35.5 (9.7)[f]	39.3 (9.9)	37.4 (10.1)
Education (% high)[a]	84	85	83	82	85
BMI	23.9 (3.5)	24.7 (3.0)	23.2 (3.8)[f]	24.1 (3.9)	23.8 (3.3)
Health attitude[b]	4.6 (0.9)	4.4 (0.8)	4.8 (0.9)[f]	4.3 (0.8)	4.7 (0.8)[g]
Taste attitude[b]	5.2 (0.7)	5.0 (0.8)	5.3 (0.7)[f]	5.4 (0.7)	5.1 (0.8)[g]
Restraint score[c]	5.0 (1.4)	5.4 (1.3)	4.7 (1.1)[f]	4.7 (1.4)	5.1 (1.2)[g]
External eating score[c]	4.5 (1.4)	4.4 (1.5)	4.6 (1.5)	4.5 (1.4)	4.6 (1.4)
Healthy snacking habit[b]	3.6 (1.2)	3.4 (1.1)	3.9 (1.2)[f]	3.0 (1.2)	3.8 (1.0)[g]
Anticipated regret for not choosing healthy[b]	2.8 (1.4)	2.5 (1.4)	3.1 (1.5)[f]	2.6 (1.5)	2.9 (1.4)
Pleasantness healthy snacks[d]	6.3 (1.4)	6.1 (1.3)	6.4 (1.4)[f]	5.4 (1.4)	6.5 (1.2)[g]
Pleasantness unhealthy snacks[d]	6.0 (1.6)	6.1 (1.6)	5.9 (1.7)	5.8 (1.7)	6.0 (1.7)
Use frequency healthy snacks (%≥1x/week)[e]	79	74	84[f]		
Use frequency unhealthy snacks (%≥1x/week)[e]	38	46	32[f]	40	38

[a] A high education level is defined as at least high level secondary education.

[b] Measured on 7-point agreement scales (left anchor = do not agree at all; right anchor = completely agree).

[c] Measured in five categories (1 = never; 5 = very often), but recoded in seven categories (1 = very low; 7 = very high).

[d] Measured on 9-point hedonic scales (left anchor = not at all pleasant; right anchor = extremely pleasant).

[e] Measured in five labeled categories, ranging from 'never' to '≥5×/week'.

[f] Significantly different from males [$p < 0.05$].

[g] Significantly different from non-frequent healthy snack consumers [$p < 0.05$].

Table 3.3: Bivariate correlations[a] between the variables which were measured at interval scale.

	Dietary restraint[c]	External eating[c]	Healthy snacking habit[b]	Anticipated regret[b]	Pleasantness healthy snacks[d]	Pleasantness unhealthy snacks[d]
Body mass index	0.15	NS	NS	NS	NS	NS
Health attitude[b]	0.31	-0.18	0.50	0.34	0.26	-0.23
Taste attitude[b]	NS	NS	NS	NS	-0.13	-0.12
Dietary restraint[c]	1	NS	NS	0.32	NS	NS
External eating[c]	NS	1	-0.22	0.13	NS	0.26
Healthy snacking habit[b]	NS	-0.22	1	0.20	0.33	-0.19
Pleasantness healthy snacks[d]	NS	NS	0.33	NS	1	0.25

[a] Only the correlations that were significant at $p < 0.01$ are shown.

[b] Measured on 7-point agreement scales (left anchor = do not agree at all; right anchor = completely agree).

[c] Measured in five categories (1 = never; 5 = very often), but recoded in seven categories (1 = very low; 7 = very high).

[d] Measured on 9-point hedonic scales (left anchor = not at all pleasant; right anchor = extremely pleasant).

Consistency between healthy intentions and actual behaviour

Of the participants, 62% (*N = 330*) intended to choose a healthy snack, while 38% (*N = 207*) intended to choose an unhealthy snack. Of the 'healthy intenders', 76% (*N= 252*) chose a healthy snack, while the remaining 24% (*N = 78*) chose an unhealthy snack. Of the 'unhealthy intenders', 69% (*N = 142*) chose an unhealthy snack.

Table 3.4: Measured variables (mean (SD) or %) of the participants, according to their actual (left) and their intended (right) choices.

	Actual choice=un-healthy (*N=221*)	Actual choice=healthy (*N=317*)	Intended choice=un-healthy (*N=207*)	Intended choice=healthy (*N=330*)
Intended choice (% healthy)	34	81[e]		
Hunger actual choice[d]	5.8 (2.5)	5.6 (2.3)		
Age	37.0 (9.7)	38.3 (10.3)	36.4 (9.4)	38.7 (10.3)[f]
BMI	24.1 (3.6)	23.7 (3.4)	23.9 (3.6)	23.9 (3.3)
Health attitude[b]	4.4 (0.9)	4.8 (0.9)[e]	4.4 (0.9)	4.8 (0.9)[f]
Taste attitude[b]	5.1 (0.7)	5.2 (0.7)	5.2 (0.8)	5.2 (0.8)
Restraint score[c]	4.9 (1.3)	5.1 (1.4)	4.8 (1.3)	5.1 (1.3)[f]
External eating score[c]	4.6 (1.5)	4.5 (1.4)	4.7 (1.4)	4.4 (1.5)[f]
Healthy snacking habit[b]	3.2 (1.0)	3.9 (1.1)[e]	3.2 (1.1)	3.8 (1.1)[f]
Anticipated regret[b]	2.6 (1.3)	3.0 (1.6)[e]	2.6 (1.4)	3.0 (1.5)[f]
Pleasantness healthy snacks[d]	6.0 (1.3)	6.5 (1.2)[e]	6.0 (1.4)	6.5 (1.2)[f]
Pleasantness unhealthy snacks[d]	6.3 (1.5)	5.7 (1.6)[e]	6.3 (1.6)	5.8 (1.7)[f]
Gender (% female)	46	61[e]	50	57
Education (% high)[a]	79	88[e]	80	87[f]
Use freq healthy snacks (%≥1x/week)	75	83[e]	73	83[f]
Use freq unhealthy snacks (%≥1x/week)	46	33[e]	47	32[f]

[a] A high education level is defined as at least high level secondary education.

[b] Measured on 7-point agreement scales (left anchor = do not agree at all; right anchor = completely agree).

[c] Measured in five categories (1 = never; 5 = very often), but recoded in seven categories (1 = very low; 7 = very high).

[d] Measured on 9-point scales (left anchor = not at all pleasant/hungry; right anchor = extremely pleasant/hungry).

[e] Significantly different from 'actual choice = unhealthy' [$p < 0.05$].

[f] Significantly different from 'intended choice = unhealthy' [$p < 0.05$].

Variables associated with an actual healthy snack choice

Table 3.4 shows the comparison between the participants who actually chose a healthy snack and those who chose an unhealthy snack. Participants who chose a healthy snack were more likely to have intended to choose a healthy snack. Moreover, they were more likely to be female and highly educated. They had a stronger health attitude, a stronger healthy snacking habit, and a higher level of anticipated regret for not choosing a healthy snack. They considered the healthy snacks more pleasant and the unhealthy snacks less pleasant. Furthermore, those who chose a healthy snack were more likely to be frequent consumers of the healthy snacks and non-frequent consumers of the unhealthy snacks than the participants who chose an unhealthy snack. The same variables also discriminated between the participants who intended to choose a healthy snack and those who intended to choose an unhealthy snack. Moreover, participants with a healthy intended choice were older, had more dietary restraint, and were less sensitive to external eating (Table 3.4).

Variables associated with the consistency between healthy snack choice intentions and behaviour

Participants with a healthy intention–behaviour consistency (H–H) were compared with participants who had a healthy intention, but an actual unhealthy snack choice (H–U). Table 3.5 shows that H–H participants were more likely to be female and highly educated. They also had a stronger health attitude, a stronger healthy snacking habit, a higher level of anticipated regret for not choosing a healthy snack, a higher perceived pleasantness of the healthy snacks and a lower perceived pleasantness of the unhealthy snacks than H–U participants.

Almost the same variables that discriminated the participants who enacted their intended healthy choice (H–H) from those who did not (H–U) discriminated the participants who did not enact their intended unhealthy choice (i.e. chose healthy) (U–H) from those who did (U–U). U–H participants were more likely to be female, had a stronger health attitude, a stronger healthy snacking habit, a higher perceived pleasantness of the healthy snacks and a lower perceived pleasantness of the unhealthy snacks than U–U participants (Table 3.5).

Table 3.5: Measured variables (mean (SD) or %) of participants according to their choice combinations (intended–actual choice).

Intended-Actual choice[g]	H-H (*N=252*)	H-U (*N=78*)	U-H (*N=65*)	U-U (*N=142*)
Hunger intended choice[d]	6.0 (2.1)	5.7 (2.0)	6.2 (2.3)	6.3 (1.9)
Hunger actual choice[d]	5.7 (2.1)	5.4 (2.2)	5.7 (2.1)	5.8 (2.0)
Age	38.6 (10.6)	38.5 (10.6)	36.6 (10.2)	35.8 (10.1)
BMI	23.8 (3.3)	24.3 (3.3)	23.7 (3.5)	24.0 (3.7)
Health attitude[b]	4.9 (0.8)	4.6 (0.9)[e]	4.6 (0.9)	4.3 (0.8)[f]
Taste attitude[b]	5.2 (0.8)	5.1 (0.8)	5.1 (0.8)	5.2 (0.8)
Restraint score[c]	5.2 (1.3)	5.0 (1.2)	4.6 (1.4)	4.9 (1.3)
External eating score[c]	4.3 (1.4)	4.5 (1.5)	4.7 (1.5)	4.7 (1.4)
Healthy snacking habit[b]	3.9 (1.1)	3.5 (1.1)[e]	3.6 (1.3)	3.1 (1.0)[f]
Anticipated regret for not choosing healthy[b]	3.1 (1.6)	2.6 (1.3)[e]	2.6 (1.5)	2.5 (1.4)
Pleasantness healthy snacks[d]	6.6 (1.3)	6.2 (1.3)[e]	6.4 (1.4)	5.9 (1.3)[f]
Pleasantness unhealthy snacks[d]	5.7 (1.7)	6.0 (1.5)[e]	5.9 (1.6)	6.5 (1.5)[f]
Gender (% female)	60.3	46.8[e]	61.5	44.4[f]
Education (% high)[a]	89.7	76.6[e]	81.1	79.6
Use freq healthy snacks (%≥1x/week)	83.7	82.1	78.5	70.4
Use freq unhealthy snacks (%≥1x/week)	30.6	38.5	41.5	50.7

[a] A high education level is defined as at least high level secondary education.

[b] Measured on 7-point agreement scales (left anchor = do not agree at all; right anchor = completely agree).

[c] Measured in five categories (1 = never; 5 = very often), but recoded in seven categories (1 = very low; 7 = very high).

[d] Measured on 9-point scales (left anchor = not at all pleasant/hungry; right anchor = extremely pleasant/hungry).

[e] Significantly different from H–H participants [$p < 0.05$].

[f] Significantly different from U–H participants [$p < 0.05$].

[g] H–H = healthy–healthy; H–U = healthy–unhealthy; U–H = unhealthy–healthy; U–U = unhealthy–unhealthy.

In the multiple regression model, intended choice and the interactions of intended choice with gender, education level, healthy snacking habit, and dietary restraint remained significantly associated with actual choice, collectively explaining 30% of the variance (Table 3.6). Females appeared to be 1.9 times as likely as males to have a healthy intention–behaviour consistency, while highly educated participants were 3.4 times as likely as lower educated participants. Each category increase in dietary restraint increased the likelihood of a healthy intention–behaviour consistency by 30%, while each point increase in healthy snacking habit increased this likelihood by 40%.

Table 3.6: Results of the stepwise logistic regression analyses to predict actual choice.

Step	Independent variable	OR healthy choice[f]	95% CI[g]	R^2 (Nagelkerke)[h]
1	**Intended choice[a]**	7.0	4.7-10.4	0.24
2	**Intended choice[a]**	0.2	0.03-0.8	0.30
	Intended choice[a] * gender[b]	1.9	1.1-3.5	
	Intended choice[a] * education[c]	3.4	1.7-6.8	
	Intended choice[a] * healthy snacking habit[d]	1.4	1.1-1.9	
	Intended choice[a] * dietary restraint[e]	1.3	1.0-1.6	

At the first step, intended choice was entered. At the second step, the interactions between intended choice and each of the measured variables were added (backward logistic regression).

[a] Reference category = unhealthy snack.

[b] Reference category = male.

[c] Reference category = low education level. A high education level is defined as at least high level secondary education.

[d] Measured on 7-point agreement scales (left anchor = do not agree at all; right anchor = completely agree).

[e] Measured in five categories (1 = never; 5 = very often), but recoded in seven categories (1 = very low; 7 = very high).

[f] OR = odds ratio, a measure for the strength of the association between a variable and the probability of a healthy actual snack choice. For example, OR of 1.2 means that increasing the level of the particular variable with one unit increases the probability of choosing a healthy snack by 20%. For categorical variables, it means that the probability of choosing a healthy snack for the participants in the category is 20% higher than for the participants in the reference category.

[g] CI = confidence interval. If the CI includes 1, the construct does not contribute significantly to the prediction of the actual choice.

[h] R^2 is the proportion of variance of actual choice that is explained by the independent variables in the model.

Snack choices classified on the basis of physical similarity instead of on the basis of healthiness

It is possible that some participants did not consider the issue of health when making their snack choice but used a different rule to be consistent. They may, for example, have chosen an alternative that was sensorily and physically similar to the intended snack instead of similar in terms of healthiness. We examined whether a categorisation in terms of physical similarity would better explain the results than a classification in terms of healthiness. Table 3.7 shows that most participants chose an alternative that was physically similar to the snack that they had intended to choose (consistent choice within a given similarity category), while the proportions of choices for each of the physically different snacks were comparable, regardless of their classification in terms of healthiness.

Discriminant analyses revealed that of the participants who intended to choose an FV snack, the FV–FV, FV–WB, and FV–SB participants had a stronger health attitude [standardized discriminant function coefficient, sdfc = 0.6] and considered the healthy snacks more pleasant [sdfc = 0.7] than the FV–SAV participants. Of the participants who intended to choose a WB snack, the WB–WB and WB–FV participants were more highly educated [sdfc = 0.9], and they considered the healthy snacks more pleasant [sdfc = 0.2] than the WB–SB and WB–SAV participants. Among the participants who intended to choose an SAV snack, the SAV–SAV and SAV–SB participants had a weaker healthy snacking habit [sdfc = −0.7] and were more sensitive to external eating [sdfc = 0.8] than the SAV–WB and SAV–FV participants. Among the participants who intended to choose an SB snack, the SB–SB, SB–SAV, and SB–WB participants were less likely to be female [sdfc = 1.0] than the SB–FV participants. In general, those who changed to a snack within the same physical similarity category (consistent choosers) could not be discriminated from those who chose a physically different snack with the same healthiness classification. However, the features of participants who chose a physically different snack with the opposite healthiness classification tended to be different (Table 3.7).

Table 3.7: Actual choice of participants, conditional on their intended choice.

Intended choice	Actual choice				
	SAV[a] *(U)*	**SB[b]***(U)*	**WB[c]** *(H)*	**FV[d]***(H)*	
SAV[a] *(U)*	45%[e]	25%[e]	6%[f]	24%[f]	100% (*N=67*)
SB[b]*(U)*	13%[g]	55%[g]	11%[g]	21%[h]	100% (*N=140*)
WB[c] *(H)*	12%[j]	18%[j]	39%[i]	32%[i]	100% (*N=108*)
FV[d] *(H)*	10%[l]	11%[k]	7%[k]	72%[k]	100% (*N=222*)

Snacks with similar characteristics were categorised in the same category.

[a] SAV: savoury or salty snack (crisps, peanuts, cheese, or sausage). A choice for a snack in this category was previously classified as 'unhealthy (U)'.

[b] SB: sweet biscuit or chocolate (candy bar, peanuts with chocolate coating, biscuit filled with almond paste, or glazed biscuit). A choice for a snack in this category was previously classified as 'unhealthy (U)'.

[c] WB: wheat biscuit (fruit biscuit, raisin biscuit, fruit bar, or gingerbread). A choice for a snack in this category was previously classified as 'healthy (H)'.

[d] FV: fruit or vegetable (apple, melon, carrot, or cherry tomato). A choice for a snack in this category was previously classified as 'healthy (H)'.

[e,f] Participants in categories with different letters could be distinguished from each other by the variables measured. Participants in SAV–WB and SAV–FV had a stronger healthy snacking habit and were less sensitive to external eating than participants in SAV–SAV and SAV–SB.

[g,h] Participants in categories with different letters could be distinguished from each other by the variables measured. Participants in SB–FV were more likely to be female than participants in SB–SB, SB–WB and SB–SAV.

[i,j] Participants in categories with different letters could be distinguished from each other by the variables measured. Participants in WB–WB and WB–FV were more likely to be highly educated and perceived the healthy snacks as more pleasant than participants in WB–SB and WB–SAV.

[k,l] Participants in categories with different letters could be distinguished from each other by the variables measured. Participants in FV–FV, FV–WB and FV–SB had a stronger health attitude and perceived the healthy snacks as more pleasant than participants in FV–SAV.

DISCUSSION

The objective of the present study was to gain insight into the factors that affect the consistency between intended and actual snack choices. We primarily examined differences between participants who enacted their healthy intended choice and those who chose an unhealthy snack instead.

Almost one out of four participants (24%) who intended to choose any of the healthy snacks chose an unhealthy snack instead. Similar inconsistencies between intentions to perform the desired behaviour and the actual behaviour were found in previous studies (e.g. Godin & Kok, 1996; Blanchard *et al.*, 2002; Orbell & Sheeran, 1998; Sheeran, Abraham, & Orbell, 1999). Behavioural theorists explain this discrepancy by the disproportionate valuation of immediate rewards (Liberman & Trope, 1998; Ariely & Zakay, 2001). Despite this discrepancy, the finding that a healthy snack choice was far more often preceded by a healthy intention than by an unhealthy intention suggests that individuals who intend to make a healthy choice seem at least more likely to do so than those who do not make such plans.

The discrepancy between healthy snack choice intentions and actual behaviour varied among the participants. Participants who were female, had a high education level, a strong healthy snacking habit, and a high dietary restraint (i.e. had a strong self-control) appeared to have a low vulnerability to a healthy intention–behaviour discrepancy. It may be that these individuals generally do not valuate immediate rewards as much as individuals who do not possess these features. Previous studies also demonstrated that strong habits or past behaviour in line with the desired behaviour (Armitage & Conner, 1999; Verplanken & Faes, 1999), and a strong self-control (Moan & Rise, 2006; Sniehotta *et al.*, 2005) enhance the intention–behaviour onsistency for all kinds of health behaviours. The influence of the demographics, gender and education level, on the healthy intention–behaviour consistency was most likely mediated by health attitude, anticipated regret for not choosing a healthy snack, and pleasantness of the healthy snacks (Armitage, Norman, & Conner, 2002). Although these variables were omitted from the regression model, their levels were higher in participants who enacted their healthy intended choice than in those who did not. As a distinction between genders and education levels reflects to a large degree a distinction between low and high levels of these variables, simply tailoring to genders and to different education levels may improve the effectiveness of interventions that aim at facilitating healthy choices. A strong health attitude (Sheeran, Norman, & Orbell, 1999) and a high level of anticipated regret (Abraham & Sheeran, 2003) have also previously been identified as enhancing the intention–behaviour consistency. Individuals who consider the healthy snacks as pleasant will not be highly vulnerable to an intention–behaviour consistency as the healthy snacks provide them with delayed as well as immediate rewards.

Although gender, education level, healthy snacking habit, and dietary restraint significantly modified the intention–behaviour consistency, the proportion of variance in behaviour that these variables explained in addition to intended choice was relatively small (collectively 6%). This might partly be caused by the fact that all these variables were also independently associated with intended choice, and correlated with each other. Additionally, the difference in the level of these variables among participants was relatively small. This may be due to the fact that most participants had similar jobs and to sampling bias (i.e. the fact that participants who had acted desirably were overly represented). Future studies should therefore investigate a more diverse population (e.g. people from several different socio-economic classes, education levels, and a broad age range).

In the present study the lack of attenuation of the healthy intention–behaviour consistency by hunger state (Loewenstein, 1996) might be explained by the fact that the study was performed around lunch time. At that time, the hungry participants may not have considered the offered snacks to immediately relieve their hunger as most of them were on their way to lunch during the choice task.

Usually, the lack of consistency between intentions and behaviour is mainly accounted for by individuals with a positive (e.g. healthy) intention who do not act accordingly (Orbell & Sheeran, 1998). However, in the present study the proportion of these types of inconsistencies (i.e. changes from an intended healthy choice to an actual unhealthy choice, H–U) was comparable with the proportion of inconsistencies in the other direction (i.e. changes from an intended unhealthy choice to an actual healthy choice (U–H), 24% vs. 31%). This may be a result of sampling bias because the questionnaire treated health issues. Therefore, participants who did not choose a healthy snack may have felt that they had acted incorrectly and therefore might have dropped-out. This is supported by the fact that the proportion of actual unhealthy choices was higher (56% vs. 41%) in the drop-outs after two choice tasks as compared to the participants who completed the study.

As the snacks were not labeled as 'healthy' or 'unhealthy' and as the participants were not interrogated about their choice motives, the study design did not guarantee that the participants' choices were health driven. The changes from healthy to unhealthy may also have been related to a shift in preference from the one time-point to another due to a general wish for variety (Ratner, Kahn, & Kahneman, 1999), while the intention–behaviour consistencies may actually have simply been due to wanting to choose an alternative that is physically and sensorily similar to the intended snack. The fact that most participants changed to a physically similar alternative did not contradict the possibility that they used a classification of physical similarity to be consistent. However, participants who changed to a physically similar alternative could only be discriminated from those who changed to a different alternative with the opposite classification in terms of healthiness, and not from participants who changed to another alternative with the same healthiness classification. This distinction was similar to the distinction between those who enacted their healthy or unhealthy intention and those who did not. For example, just as participants who enacted their healthy intended choice vs. those who chose an unhealthy snack, participants who enacted their intention to choose a fruit or vegetable snack had a stronger health attitude and considered the healthy snacks more pleasant than participants who changed to a salty or savoury snack. This suggests that a classification of the snack choices in terms of healthiness better explained the results than a categorisation of the snack choices in terms of physical similarity. Moreover, this supports that most participants classified the snacks as healthy and unhealthy in the same way that the investigators did and that the choices of the participants were, to some extent, health driven.

A clear strength of this study is that it is one of the few studies in which eating behaviour was actually observed in a naturalistic setting instead of reported by the participants (see also: Louis *et al.*, 2007; Read & Van Leeuwen, 1998). The latter was the case in most previous studies that investigated the intention–behaviour consistency for healthy eating (e.g. Brug *et al.*, 2006; Jackson *et al.*, 2005; Verbeke & Pieniak, 2006; Sparks *et al.*, 2001), despite evidence to suggest the vulnerability of such data to self-presentational biases (Gaes, Kalle, & Tedeschi, 1978).

The design of the present study is limited in the following ways. First, the study only consisted of a single intended and actual choice task instead of repeated choice tasks. Therefore, we could not take into account situational factors that might affect choice and 'intention stability' (Sheeran & Abraham, 2003). Another possible design limitation was the presence of participants' colleagues during the choice tasks. This may have enhanced socially desirable behaviour and therefore increased the number of choices for a healthy snack. The study situation, however, may reflect the normal choice situation at work, as others are usually present when food choices are made in a worksite cafeteria. Furthermore, the choice of in-between meal snacks was studied at a time-point that is actually inappropriate to study this type of choice, i.e. during lunchtime. This time-point was chosen because lunchtime was the only possibility to recruit participants in worksite cafeterias. Although we underlined that the snack would be for consumption during the afternoon, the choices would probably have been more valid if the study had been performed at an appropriate snacking time. Moreover, despite the instructions, some participants may not have consumed the chosen snack but may have thrown it away or given it to someone else. Ideally, future studies that investigate the issue of intention–behaviour discrepancies in food choice should observe all of their participants' food choices for a follow-up time of a set number of days or weeks. However, the burden for participants would be enormous and the awareness that their food choices were being observed would most likely lead to many socially desirable choices.

In conclusion, these results suggest that the inconsistency between healthy food choice intentions and actual behaviour is substantial. However, making a healthy intention seems to be more supportive for actually making a healthy food choice than not making such a plan. To facilitate the healthy intention–behaviour consistency in snack choice, interventions should target males and lower educated people, and focus on increasing their healthy snacking habit and self-control. Meanwhile, the food industry should aim at developing healthy but pleasant snacks. However, before firm recommendations are made, the results of this study should be replicated in a study that includes a broader population in which intention and behaviour are repeatedly measured at appropriate time-points, in which participant's intentions are confirmed as health driven or not and in which social desirability and response bias are reduced.

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4

Effects of complexity and intensity on sensory specific satiety and food acceptance after repeated consumption

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The objectives of the present work were 1) to study the effects of complexity and intensity of foods on sensory specific satiety (SSS) and their acceptance after repeated consumption, and 2) to determine the predictive value of SSS for acceptance over repeated consumption. Two studies were performed: a soup study (*N=66*) and a snack study (*N=61*). In the snack study, the intense snacks produced somewhat more SSS than the less intense snacks [$F(3,177) = 2.2$, $p=0.09$]. Both studies demonstrated that pleasantness of stimuli with a near to optimal arousal level, which is a combination of complexity and intensity, was more resistant to a decline over repeated exposure than of stimuli with lower arousal levels [soups: $F(14,546) = 2.0$, $p=0.04$; snacks: $F(15,450) = 6.1$, $p=0.003$]. The data do not support the idea that SSS could serve as a rapid predictor of long-term acceptance [soups: $r_{\text{SSS-repeated consumption}} = -0.05$, $p=0.73$; snacks: $r_{\text{SSS-repeated consumption}} = 0.20$, $p=0.19$]. These findings need to be confirmed with stimuli that are more comparable with respect to initial liking and sensory qualities other than intensity and complexity.

Keywords: Food acceptance; Consumer exposure test; Sensory specific satiety; Complexity; Intensity

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INTRODUCTION

The acceptance of foods changes over repeated exposure, showing either sustained acceptance, an increase in acceptance, or a decrease in acceptance (e.g. Levy & Köster, 1999; Mela, 2000). Acceptance of novel foods may increase with repeated exposure, while acceptance of familiar foods may decrease with repeated exposure, resulting in boredom.

The changes in acceptance appear to depend on certain sensory properties of foods. It is not clear, however, which sensory properties of stimuli drive or reduce long-term acceptance. Vickers and Holton (1998) indicated that the intensity level of stimuli might influence acceptance over repeated exposure; they showed that tea of low intensity was preferred to intense tea across 20 consumption sessions. The finding that the acceptance of intense stimuli rapidly declines over repeated exposure has been confirmed by others (Zandstra, De Graaf, Mela, & Van Staveren, 2000; Chung & Vickers, 2007)

Besides intensity, a change in acceptance after repeated exposure may relate to the perceived complexity of the stimuli. The concept complexity is either defined a priori on the basis of information-theoretical considerations (e.g. number of bits in a pattern) or is measured with the help of rating scales or paired comparison. Different stimuli have been used to test the association between complexity and acceptance, i.e. music, words, visual stimuli (Berlyne, 1970), fragrances (Jellinek & Köster, 1979; 1983) and foods. Levy, MacRae and Köster (2006) found that liking for complex orange drinks increased with repeated exposure, while the same effect was not demonstrated after repeated exposure to simple orange drinks. Yet, in an experiment with flavoured crackers, Porcherot and Issanchou (1998) could not ascertain the relation between perceived complexity and acceptance over repeated exposure.

According to Berlyne (1960; 1970), it is actually the arousal level of a stimulus, which is the combination of intensity, complexity, and novelty, which determines the degree of acceptance of the stimulus. Berlyne (1960; 1970) proposed an inverted *U*-form relationship between arousal potential and acceptance, indicating that for each individual there is an optimal arousal potential level below and above which stimuli are liked less. This optimal level is different for different people and depends on learning and experience (Berlyne, 1974). Dember and Earl (1957) explained this learning-effect by assuming that repeated exposure to a somewhat more than optimally arousing stimulus increases the individual's optimal arousal, and as a result, the arousal of stimuli in the same category diminishes and acceptance of the stimulus improves. Repeated exposure to a stimulus with a lower than optimal arousal level, on the other hand, would not affect the optimal arousal level, and therefore result in a decline in acceptance and boredom. As a consequence, products that are introduced on the market should have a slightly higher arousal level than optimal arousal in order to be accepted on the longer term (Köster, 2003).

Long-term acceptance of food products can be established by a consumer exposure test of several days or even weeks. However, as this is very time-consuming and expensive, a short test that predicts longer-term acceptance well would be attractive. It is clear that first time hedonic impressions are no good predictors for liking over repeated exposure (e.g. Levy & Köster, 1999; Vickers & Holton, 1998; Lucas & Bellisle, 1987). As a quick method to predict boredom, Moskowitz (2000) developed a time-preference measurement test, based on the assumption that a consumer can give a reliable interest rating for a food, when asked to imagine that s/he has not used the product for a certain period. However, Zandstra, Weegels, Van Spronsen and Klerk (2004) and Kahneman and Snell (1992) could not validate this idea. Porcherot and Issanchou (1998) tried to predict long-term acceptance with a laboratory test in which liking of the same cracker was rated 18 times in a row. The results of their in-home consumer exposure test did however not reflect the results of the laboratory test.

It has been suggested that sensory specific satiety (SSS), which is a decrease in pleasantness of the food that has been eaten relative to non-eaten foods (Rolls, Rowe, & Rolls, 1982; Rolls, Rolls, Rowe, & Sweeney, 1981), may be related to long-term acceptance of food (Rolls & De Waal, 1985; Vickers & Holton, 1998; Chung & Vickers, 2007). Therefore, SSS could perhaps be used as a rapid predictor of longer-term acceptance of foods. In support of this, Weenen, Stafleu and De Graaf (2005) found an effect of eating cheese biscuits to satiety in an SSS test on liking ratings for cheese biscuits in the following six day in-home consumption study. Vickers and Holton (1998) found that the amount of tea consumed during an SSS test might be a good indicator of long-term acceptability. In contrast, Chung and Vickers (2007) demonstrated an increase in liking for low sweet tea with repeated consumption, which was not predicted by sensory specific satiety.

In the present paper, two studies are described to investigate the sensory properties complexity and intensity, and a combination of these properties, i.e. arousal, as determinants of sensory specific satiety (SSS) and acceptance after repeated consumption. In the first study (hereafter named soup study), soups were eaten, and in the second study (hereafter named snack study), biscuits and chocolate products were eaten as snacks. The designs and procedures of the two studies were similar.

METHODS

Participants

Participants were healthy consumers, mainly students and staff of Wageningen University (NL). Sixty-eight participants were recruited in the soup study. For the analysis of the SSS test data, records of 62 (mean age: 26.7 (SD=11.7); % male: 29.0) of the 68 participants were considered, as 6 participants did not fully complete the questionnaires. For comparison of intake among the soups, 2 additional participants were excluded, as we accidentally did not measure their intake of one of the soups. For analysis of the consumer exposure test data, data of 66 out of the same 68 participants (mean age: 27.6 (SD=12.0); % male: 29.9) were used. Two participants were excluded, as one of them did not return the questionnaires, and the other forgot to consume the soup for 2 days (out of 14).

A new group of 61 participants (mean age: 23.8 (SD=6.3); % male: 45.9) was recruited for the snack study. All their data were used for analysis of the SSS test. Data of 53 of them (mean age: 23.9 (SD=6.7); % male: 47.2) were used for statistical analysis of the consumer exposure test results. The other 8 were excluded, as they missed two or more sessions (out of 20).

In both studies, participants were naïve to the aim of the study. They were told that they would assess different prototypes of the products in subsequent sessions.

Products

The products used in both studies were all from the same batch and commercially available in supermarkets at the time of the study.

In the soup study, in the SSS test, three soups with a chicken flavour base were used, slightly varying in complexity and intensity (<2 points on a 9-point scale); (A) regular chicken soup, (B) Asian chicken soup, and (C) a chicken soup with a familiar flavour but new to chicken soup. In the consumer exposure test only soup A and soup C were used, as they were, respectively, the least and most complex and intense. All soups were initially equally well liked (Table 4.1). The three soups were selected on the basis of a pilot study (*N=11*). Of the nine soups tested, these three were perceived as the least, middle and most complex.

Table 4.1: Comparison of attribute ratings (mean ± SEM) among the soups, in the SSS test and the consumer exposure (cons. exp.) test. Ratings on a 9-point scale, anchored from 1=not at all.. to 9=extremely.. (SSS test: *N=62*; Consumer exposure test: chicken soup A *N=33*, chicken soup C *N=33*).

Attribute	Test	Chicken soup A	Chicken soup B	Chicken soup C	*P*-value
Initial pleasantness	*SSS*	5.9 (0.2)	5.8 (0.2)	6.3 (0.2)	0.11
	Cons. exp.	6.3 (0.3)		6.6 (0.3)	0.40
Intensity	*SSS*	5.0 (0.2) [a]	5.6 (0.1) [b]	6.9 (0.1) [c]	<0.001
	Cons. exp.	4.5 (0.3)		6.4 (0.2)	<0.001
Complexity	*SSS*	4.2 (0.2) [a]	5.0 (0.2) [b]	6.4 (0.2) [c]	<0.001
	Cons. exp.	4.1 (0.2)		6.0 (0.3)	<0.001
Appropriateness	*SSS*	5.5 (0.2)	5.5 (0.2)	5.4 (0.3)	0.94
	Cons. exp.	4.1 (0.4)		4.9 (0.4)	0.15
Novelty	*SSS*	3.6 (0.2) [a]	4.6 (0.2) [b]	5.4 (0.2) [c]	<0.001
Difficulty to describe	*Cons. exp.*	3.9 (0.3)		5.4 (0.3)	0.001

[a,b,c] Within rows, means with different letters differ statistically significantly from each other [$p<0.05$].

In the snack study, four snacks were used that were clearly different in taste and texture. The snacks were chosen on the basis of a pilot study (*N=19*) with 6 snacks. The snacks were chosen to cover a wider range of complexity and intensity (± 5 cm on a 10 cm line scale), and to make complexity and intensity separable, in contrast to the soup study; (1) candy bar with chocolate and nuts (458 kcal/100g), (2) wholemeal biscuit with chocolate (458 kcal/100g), (3) plain chocolate (570 kcal/100g), and (4) tea biscuit, which is a plain wheat biscuit (437 kcal/100g). The candy bar with chocolate and nuts was slightly more pleasant than the other snacks. The candy bar with chocolate and nuts was perceived as both highly complex and intense; the wholemeal biscuit with chocolate was high in complexity, but lower in intensity; the plain chocolate was low in complexity, but highly intense; the tea biscuit was both low in complexity and intensity (Table 4.2).

Table 4.2: Comparison of attribute ratings (mean ± SEM) among the snacks, in the SSS test and the consumer exposure (cons. exp.) test. Ratings on a 10 cm line scale, anchored from 'not at all…' on the left, until 'extremely…' on the right.

Attribute	Test	Candy bar with chocolate and nuts	Wholemeal biscuit with chocolate	Plain chocolate	Tea biscuit
Initial desire to eat	*SSS (N=60)*	6.1 (0.2) [d]	5.1 (0.2) [c]	4.8 (0.3) [b,c]	4.4 (0.2) [a,b]
	Cons. exp. (N=53)	6.3 (0.3) [c]	5.5 (0.3) [b]	5.1 (0.4) [a,b]	4.5 (0.4) [a]
Initial pleasantness	*SSS (N=60)*	7.4 (0.2) [b]	5.5 (0.3) [a]	5.2 (0.3) [a]	5.3 (0.3) [a]
	Cons. exp. (N=53)	7.2 (0.3) [c]	5.8 (0.3) [b]	5.1 (0.4) [a,b]	4.7 (0.3) [a]
Complexity	*SSS (N=59)*	7.3 (0.2) [d]	5.5 (0.3) [c]	3.0 (0.2) [b]	1.8 (0.2) [a]
Intensity	*SSS (N=58)*	7.2 (0.2) [c]	4.2 (0.2) [b]	7.0 (0.2) [c]	2.7 (0.2) [a]

[a,b,c,d] Within rows, means with different letters differ statistically significantly from each other [$p<0.05$].

Design

Upon participation in the studies, subjects completed a questionnaire on demographic characteristics, length, weight, dietary restraint (Dutch Eating

Behaviour Questionnaire, Van Strien, Frijters, Bergers, & Defares, 1986), allergies for ingredients of the products used in the studies, and liking of the flavours of the products used.

In both studies, we first performed a laboratory sensory-specific satiety (SSS) test, and next a consumer exposure test. A consumer exposure test consists of repeated consumption of products over several days or weeks. The design of the SSS tests was similar to that of other previous SSS studies (e.g. Rolls *et al.*, 1981). Participants came to the laboratory, and tasted and rated a number of foods, with respect to acceptance. This tasting set consisted of the 3 soups in the soup study, and of the 4 snacks in the snack study. Subsequently, they ate a large amount of one of the foods (the test-food), and next tasted and rated the same foods again. In the soup study, the participants were instructed to eat an *ad libitum* amount of the test-soup, served in a bowl with 560g of soup. In the snack study, the participants consumed a fixed amount of the test-snack, which consisted of 275 kcal (wholemeal biscuit with chocolate: 60.0g, tea biscuit: 61.3g, candy bar with chocolate and nuts: 60.0g, plain chocolate: 48.2g), of the particular snack. This was the average amount women could eat in a pilot study without developing aversion. We kept the caloric intake equal among the snacks to make sure that a possible difference in the decrease in acceptance ratings among the snacks would not be confounded by a difference in physiological satiety caused by a difference in caloric intake. Besides, the energy density of the snacks was almost equal, except for the plain chocolate, which had a slightly higher energy density.

In the soup study, each subject came twice and tested the soup with the highest intensity and complexity (chicken soup C) once, and the soup with the lowest intensity and complexity (chicken soup A) once. In the snack study, each subject came 4 times and tested all snacks once. Both the order of serving test-foods and the order of tasting and rating were randomized across and within participants in both studies.

In the soup study, the consumer exposure test was performed at home, for fourteen consecutive days. Each subject daily consumed one cup, 187g, of either the most complex and intense soup (chicken soup C), or the least complex and intense soup (chicken soup A). The soups were supplied to participants in branded one-person portions. The brand was the same for both soups, and the appearance of the sachets in which they were supplied was exactly the same, except for the name of the soup. From the inclusion questionnaire, it appeared that 17 participants disliked the flavour of soup C (particular flavour added to the chicken broth). After assigning these latter participants (*N=17*) to the group who would receive soup A (chicken broth without added flavours), the other participants were randomly allocated to one of the groups. In the snack study, the consumer exposure test was performed at the research facility, in a within-subjects design for five consecutive days per snack. The order of snack consumption was randomized across and within participants. The first 4 days of each snack, female participants consumed 275 kcal (wholemeal biscuit with chocolate: 60.0g, tea biscuit: 61.3g, candy bar with chocolate and nuts: 60.0g, plain chocolate: 48.2g), while male participants consumed 450 kcal of the snack (wholemeal biscuit with chocolate: 100.0g, tea biscuit: 103.0g, candy bar with chocolate and nuts: 100.0g, plain chocolate: 79.6g). The 5^{th} day, participants were allowed to consume an *ad libitum* amount of the snack. The snacks were cut into equal pieces and supplied on a plate.

Experimental Procedure

Sensory Specific Satiety test (SSS test): In both studies, the laboratory sessions were separated by at least 24hrs. Participants were asked to taste all products one by one in random order and to rate them both hedonically and analytically in each session. The participants were instructed to swallow a mouthful of the products and to rinse with water and crackers between the samples. Then, they received a larger amount of one of the products, the test-product. After consumption of the test-product, the participants tasted all products again and re-rated them. In the soup study, the attributes pleasantness, complexity, familiarity, intensity, and appropriateness to eat each day were rated on a 9-point scale, anchored at both sides (from 'not at all..' to 'extremely..'). As it was previously recognized that complexity consists of several dimensions, three items were used to measure this dimension (Porcherot, 1995). The complexity items were 'complex' (this soup is not at all/extremely complex), 'number of ingredients' (this soup is composed of very few/very many ingredients) and 'difficulty to describe' (the taste of this soup is not at all/extremely difficult to describe). Principal component analysis performed over the 3 complexity items and the familiarity item showed that the items ‘complex’ and ‘number of ingredients’ could be described by one dimension, related to complexity [rotated factor loadings 0.95 and 0.91 for complex and number of ingredients, respectively]. Also the items ‘familiar’ and ‘difficult to describe’ could be described by one dimension [rotated factor loadings -0.87 and 0.80 for familiar and difficult to describe, respectively], indicating that a soup perceived as easy to describe was also perceived as familiar. Thus, ‘difficulty to describe’ seemed to measure a dimension related to familiarity/novelty rather than a complexity dimension. This is consistent with earlier findings (Sulmont, Issanchou, & Köster, 2002). These results led us to calculate two indexes: an index of complexity by averaging the scores of the items complexity and number of ingredients, and an index of novelty by averaging the scores of the items familiarity and difficulty to describe, after the scores of familiarity were recoded.

As from the soup study it appeared that complexity could be described by only 1 item, in the snack study only the item ‘complex’ (this snack is not at all/extremely complex) was used to measure the dimension complexity. The other attributes rated in the snack study were desire to eat (before tasting), pleasantness, and intensity. All attributes were rated on a 10cm line scale, anchored at both sides (from ‘not at all..’ to ‘extremely..’).

Part 2: Consumer exposure test: At each consumption moment, participants were asked to rate the products on a number of attributes, just before and right after consumption of the products. In the soup study, desire to eat the soup was rated just before consumption, while pleasantness and desire for a second cup were rated right after consumption, on a 9-point scale (anchored from ‘not at all..’ to ‘extremely..’). In the snack study, hunger, desire to eat the snack, and probability of choosing the snack if the choice was theirs were rated just before consumption. Pleasantness, interestingness, boredom, and probability of choosing the same snack the next day if the choice was theirs were rated right after consumption, all on a 10cm line scale (anchored from ‘not at all..’ to ‘extremely..’). Moreover, participants were asked to record the time they needed to consume the snacks. Snack intake on the 5th day was measured by weighing the leftovers on the plate.

Data analysis

All data analyses were performed with SPSS 12.0.1 for Windows. Effects were considered statistically significant at a value of $p<0.05$.

Attribute ratings: As in both studies, the individual ratings of initial pleasantness, desire to eat (only snack study), complexity, intensity, novelty (only soup study), and appropriateness (only soup study) per product were consistent across the SSS sessions (assessed by repeated measures GLM with session as within-subjects factor), individual mean ratings per product were calculated. Repeated measures GLM (within-subjects factor: soup or snack), followed by a Bonferroni's post-hoc test, was carried out on these mean ratings to determine differences between the soups and snacks, respectively.

Sensory specific satiety: We calculated SSS scores for each product by subtracting the change in acceptance ratings for the eaten product (i.e. the soup or snack test-product) from the mean change in acceptance ratings for the non-eaten products. A positive score indicates that the decline in ratings of the eaten product (test-product) was larger than the mean decline of the non-eaten products. To determine possible differences in the amount of SSS between the products, the SSS scores were compared across the eaten products by a Student's T-test for paired samples in the soup study and by repeated measures GLM (within-subjects factor: eaten product) in the snack study (Rolls & McDermott, 1991).

Decline in acceptance after repeated exposure, analysed at product level: The change in the different acceptance ratings over repeated exposure to the products was analysed by repeated measures GLM. In the models, product rating was the dependent variable. Day, product, and the interaction day x product were the independent variables (Zandstra, De Graaf, & Van Trijp, 2000). The linear trend point replaced the missing values of participants who missed one session. As consumption of the soups and snacks in the SSS test affected the acceptance ratings at the start of the consumer exposure test, the change in the acceptance ratings that were measured in both tests (soup study: pleasantness; snack study: desire to eat and pleasantness) was investigated from the SSS test to the end of the consumer exposure test. The initial rating in the SSS test was thus included as the first rating. For the acceptance ratings that were only measured in the consumer exposure test, the rating on the first day of that test was used as the first rating. Besides, individual-level regression analyses were performed to calculate individual slopes of the acceptance ratings over repeated exposure. To investigate the difference in slopes among the products, mean individual slopes were calculated for each product, and these were compared by Student's T-tests for independent samples (soup study) or by repeated measures GLM (snack study).

Decline in acceptance after repeated exposure, analysed at arousal level: Repeated measures GLM was also performed here, using 'individual arousal ranking' as independent variable, instead of 'product'. Arousal level, a composite of complexity and intensity (Berlyne, 1970), was calculated for each product by adding the individual scores on complexity and intensity as assessed in the SSS test. Per individual, rankings were assigned to the arousal levels of each product (product with lowest arousal level: ranking = 1; product with highest arousal level: ranking = 2 in soup study, and ranking = 4 in snack study). As the arousal rankings should be considered relative to each individual's optimal (most preferred) arousal (Berlyne, 1970), we performed subgroup analyses for each group of participants with the same optimal rank of arousal (e.g. soup study: separate analyses for participants who preferred the soup with ranking 1, and for participants who preferred the soup with ranking 2). However, for both studies, we only report the analysis for participants who preferred the product with the highest arousal ranking. The other groups of participants were very small (soup study: N(optimal = highest arousal) = 41; N(optimal = lowest arousal) = 25; snack study: N(optimal = highest arousal) = 31; N(optimal = one but highest arousal) = 12; N(optimal = one but lowest arousal) = 5; N(optimal = lowest arousal) = 5).

Validation of SSS test as predictor of acceptance over repeated exposure: To put the results of the SSS test and the results of the consumer exposure test side by side, individual changes in pleasantness of the eaten product in the SSS test were compared with the changes in pleasantness of the same product in the consumer exposure test. In the soup study, the ratings were compared by calculation of a Spearman's correlation coefficient. In the snack study, Pearson within-subject correlation coefficients were calculated. As each of these correlations consisted of only four pairs of data, these were first rescaled to a normal distribution by z-transformation, $z = 0.5 \ln (1 + r)/(1 -$

r), and then averaged. The average z-score was then transformed back to the mean correlation coefficient, $r = (e^{2z} - 1)/(e^{2z} + 1)$ (Snedecor & Cochran, 1980). By means of one sample T-tests was tested if the z-transformed values differed from zero. If yes, we would conclude that there was a significant association between the changes in pleasantness in both tests.

Association pleasantness – intake: In the soup study, Spearman's correlation was used to assess the relation between the individual mean initial pleasantness ratings of the soups and *ad libitum* intake in the SSS test. In the snack study, a difference in intake on the 5th day (in kcal, as well as in g) among the 4 snacks was assessed by repeated measures GLM (within participants factor: product), followed by a Bonferroni's post-hoc test. Pearson within-subject correlation coefficients between intake on the 5th day (in kcal) and respectively initial pleasantness, desire and boredom were calculated for each subject separately. These correlation coefficients were rescaled to a normal distribution as described above (Snedecor & Cochran, 1980), and averaged. A one sample T-test was used to test if the z-transformed values differed from zero.

RESULTS

Sensory specific satiety

In the soup study, the decrease in pleasantness of the eaten soups was similar to that of the uneaten soups [soup A: $F(2,122) = 1.2$, p=0.32; soup C: $F(2,122) = 1.5$, p=0.23], thus no sensory specific satiety (SSS) developed. As a consequence, there was no difference between the soups in the amount of SSS produced [$t(61) = -1.3$, p=0.21] (Figure 4.1).

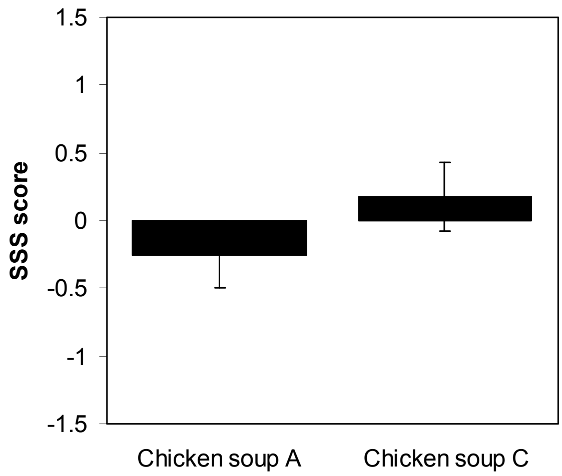

Figure 4.1: SSS scores (±SEM) for both soups (*N=62*). SSS scores were calculated for each soup by subtracting the decrease in pleasantness of the test-soup from the decrease in pleasantness of the other, non-eaten, soups.

In the snack study, upon consumption, the pleasantness of the plain chocolate [$F(3,180) = 10.5$, $p<0.001$], the candy bar with chocolate and nuts [$F(3,180) = 7.3$, $p<0.001$], and the tea biscuit [$F(3,177) = 4.6$, $p=0.004$] decreased more than the pleasantness of the other non-eaten snacks. After consumption of the wholemeal biscuit with chocolate, its pleasantness decreased only slightly (not statistically significantly) more than the pleasantness of the other snacks [$F(3,180) = 0.9$, $p=0.46$]. The difference in SSS scores between the snacks was borderline statistically significant [$F(3,177) = 2.2$, $p=0.09$]. After consumption of plain chocolate the most SSS developed, followed by the candy bar with chocolate and nuts, then the tea biscuit, and the least SSS developed for the wholemeal biscuit with chocolate (Figure 4.2). For desire to eat the snacks, a similar pattern could be observed [$F(3,177) = 2.4$, $p=0.07$] (data not shown).

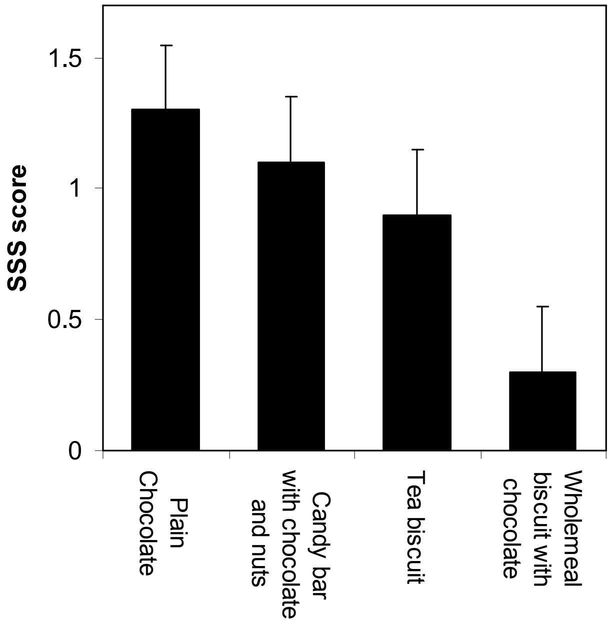

Figure 4.2: SSS scores (±SEM) for each snack (*N=60*). SSS scores were calculated for each snack by subtracting the decrease in pleasantness of the test-snack from the decrease in pleasantness of the other, non-eaten, snacks.

Effect of consumption of the stimuli in the SSS test on acceptance ratings and the impression of complexity and intensity

There was a trend for the pleasantness of both soups to increase from the SSS test to the first exposure in the consumer exposure test (Table 4.1), although this trend was only statistically significant for chicken soup A [p=0.02]. In the case of the snacks, at least for desire to eat the snacks, the same trends could be observed (Table 4.2), even though none of these changes were significant. Moreover, for both soups the impression of intensity and complexity seemed to decrease from the SSS test to the first exposure in the consumer exposure test (Table 4.1). Both trends were statistically significant for chicken soup C [p=0.03 and p=0.001, respectively].

Decline in acceptance after repeated exposure, analysed at product level

The changes in pleasantness and desire to eat over repeated exposure differed among the snacks [pleasantness: $F(15,780) = 4.5$, $p=0.001$; desire to eat ($F(15,780) = 2.0$, $p=0.03$]. For the wholemeal biscuit with chocolate and for the candy bar with chocolate and nuts these ratings remained rather stable, or even increased (in the case of pleasantness of the wholemeal biscuit with chocolate) (Figure 4.3). For the plain chocolate and the tea biscuit the ratings declined over repeated exposure. These findings suggest that the acceptance over repeated exposure was better for the complex snacks than for the less complex snacks. Boredom ratings were for all snacks stable over repeated exposure [time effect: $F(4,208) = 0.7$, $p=0.62$; time x product effect: $F(12,624) = 0.7$, $p=0.75$]. Interestingness declined comparably for all snacks over repeated exposure [time effect: $F(4,208) = 5.4$, $p<0.001$; time x product effect: $F(12,624) = 1.2$, $p=0.29$]. The means of the individual slopes support the findings that the changes in pleasantness and desire over repeated exposure were different among the snacks, while there were no differences among the snacks for the changes in boredom and interestingness (Table 4.3).

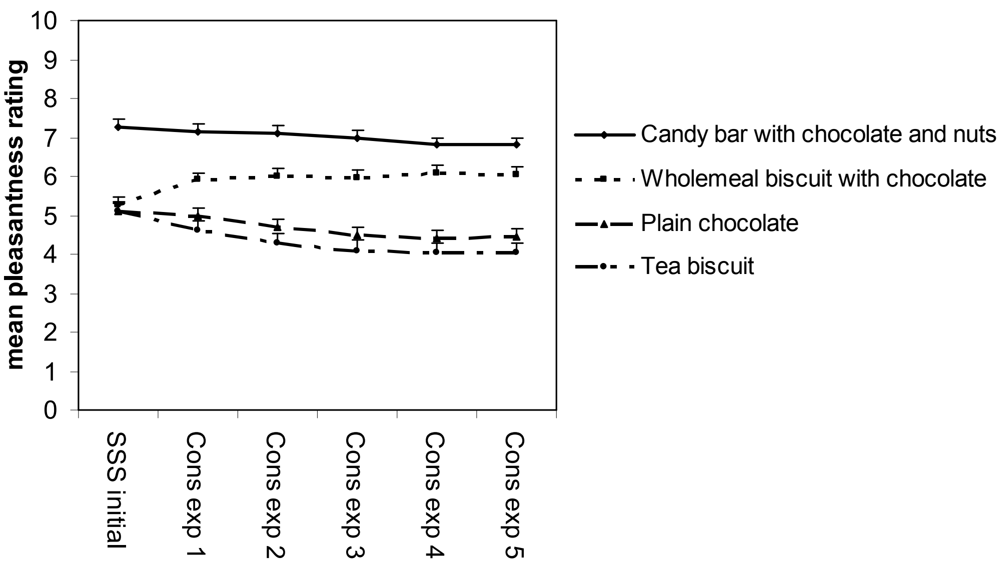

Figure 4.3: Course of pleasantness ratings (mean+SEM) of the snacks over time, from the SSS test until day 5 of the consumer exposure test (*N=53*). Pleasantness was rated on a 10cm line scale (left anchor: not at all pleasant; right anchor: extremely pleasant).

Table 4.3: Comparison of the mean (± SEM) of the individual slopes of acceptance ratings over time among the snacks (*N=53*).

Attribute	Candy bar with chocolate and nuts	Wholemeal biscuit with chocolate	Plain chocolate	Tea biscuit	*P*-value
Desire to eat	-0.01 (0.05) [b]	-0.03 (0.07) [b]	-0.26 (0.06) [a]	-0.18 (0.06) [a,b]	0.007
Pleasantness	-0.07 (0.04) [a]	0.10 (0.06) [b]	-0.14 (0.05) [a]	-0.19 (0.06) [a]	0.001
Interestingness	-0.31 (0.09)	-0.09 (0.10)	-0.23 (0.12)	-0.05 (0.11)	0.07
Boredom	0.04 (0.14)	0.07 (0.09)	-0.01 (0.12)	-0.01 (0.10)	0.95

For desire to eat and pleasantness the slopes reflect the changes from the SSS test until day 5 of the consumer exposure test. For interestingness and boredom the slopes reflect the changes from day 1 until day 5 of the consumer exposure test.

[a,b] Within rows, means with different letters differ statistically significantly from each other [$p<0.05$].

In the soup study, we could not confirm the idea that complexity enhances sustained acceptance. Pleasantness declined comparably for both soups over repeated consumption [time effect: $F(14,812) = 5.6$, $p<0.001$; time x soup effect: $F(14,812) = 0.82$, $p=0.65$] (Figure 4.4). The ratings of desire to eat just before consumption and desire for a second cup showed a pattern similar to the pleasantness ratings. For both ratings, the mean decline over time was statistically significant [desire: $F(13,832) = 3.1$, $p<0.001$; desire for a second cup: $F(13,832) = 2.3$, $p=0.006$], and was similar for both soups [desire: $F(13,832) = 0.7$, $p=0.80$; desire for a second cup: $F(13,832) = 1.0$, $p=0.50$]. The means of the individual slopes of pleasantness, desire, and desire for a second cup over time support these findings (Table 4.4).

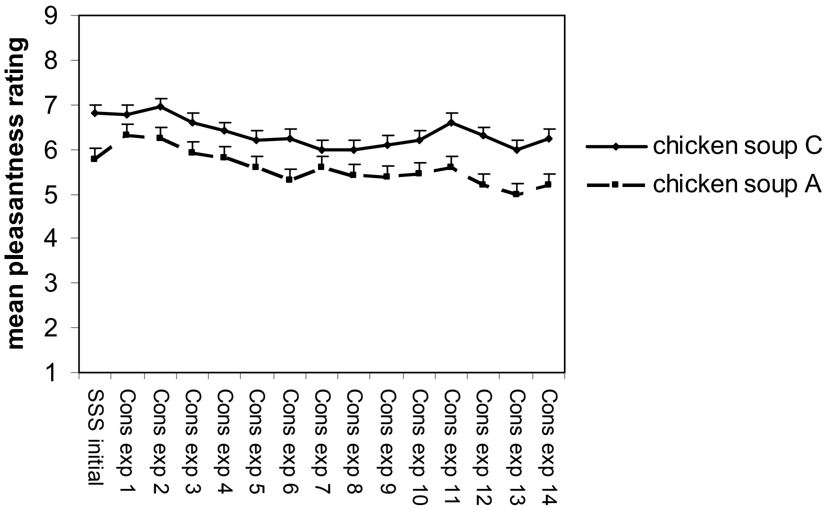

Figure 4.4: Course of pleasantness ratings (mean+SEM) of the soups over time, from the SSS test until day 14 of the consumer exposure test (chicken soup A *N*=33, chicken soup C *N*=33). Pleasantness was rated on a 9-point scale (left anchor: not at all pleasant; right anchor: extremely pleasant).

Table 4.4: Comparison among the soups of the mean (± SEM) of the individual slopes of acceptance ratings over time in the consumer exposure test (chicken soup A *N*=33, chicken soup C *N*=33).

Attribute	Chicken soup A	Chicken soup C	*P*-value
Desire to eat	-0.09 (0.07)	-0.24 (0.07)	0.15
Pleasantness	-0.07 (0.03)	-0.05 (0.02)	0.49
Desire for a second cup of the same soup	-0.09 (0.05)	-0.15 (0.06)	0.45

For pleasantness the slopes reflect the changes from the SSS test until day 14 of the consumer exposure test. For desire to eat and desire for a second cup the slopes reflect the changes from day 1 until day 14 of the consumer exposure test.

Decline in pleasantness after repeated exposure, analysed at arousal level

Among the participants for whom the soup with the highest arousal level (this was soup C for most participants (39 out of 41)) was closest to their individual optimal arousal level, the pleasantness over repeated exposure of the soup with this highest arousal level was stable over repeated exposure, while the pleasantness of the soup with the lowest arousal level declined [$F(14,546) = 2.0$, p=0.04] (Figure 4.5).

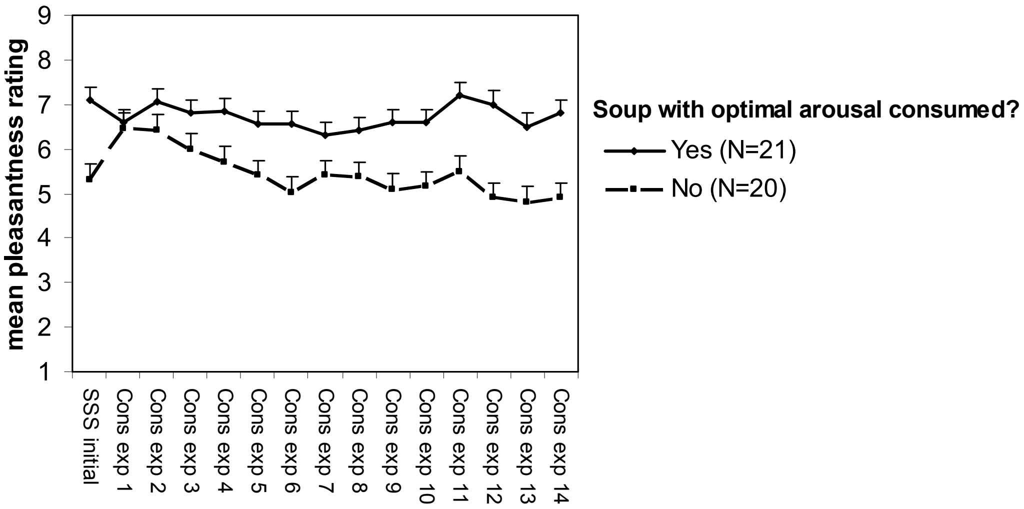

Figure 4.5: Course of pleasantness ratings (mean+SEM) of the soups with the highest (=optimal), and lowest arousal level over time, from the SSS test until day 14 of the consumer exposure test. Pleasantness was rated on a 9-point scale (left anchor: not at all pleasant; right anchor: extremely pleasant). The points represent the collection of different soups that according to the participants came in 1st or 2nd place of arousal level.
The figure only represents the participants who preferred the soup with the highest arousal level over the soup with the lowest arousal level (*N=41*). About half of them actually had that soup to eat during the consumer exposure test (*N=20*), while the other half had the soup with the lowest arousal level to eat during the consumer exposure test (*N=21*).

In the snack study, a similar association between arousal level and pleasantness over repeated exposure was found. For participants whose most preferred snack was the snack with the highest arousal level (which was the candy bar with chocolate and nuts for most participants (29 out of 31)), the pleasantness of this snack first steeply increased and then slightly declined over time. The pleasantness of the snacks with the lower arousal levels declined more continuously over time [$F(15,450) = 6.1$, $p=0.003$] (Figure 4.6). These findings thus suggest that a close to optimal arousal level enhances acceptance over repeated exposure of foods. In both studies, there was a strong positive association between arousal level and initial pleasantness [soup study: $r = 0.30$, $p=0.001$; snack study: $r=0.60$, $p<0.001$], i.e. the higher the arousal level, the higher the initial pleasantness of the products.

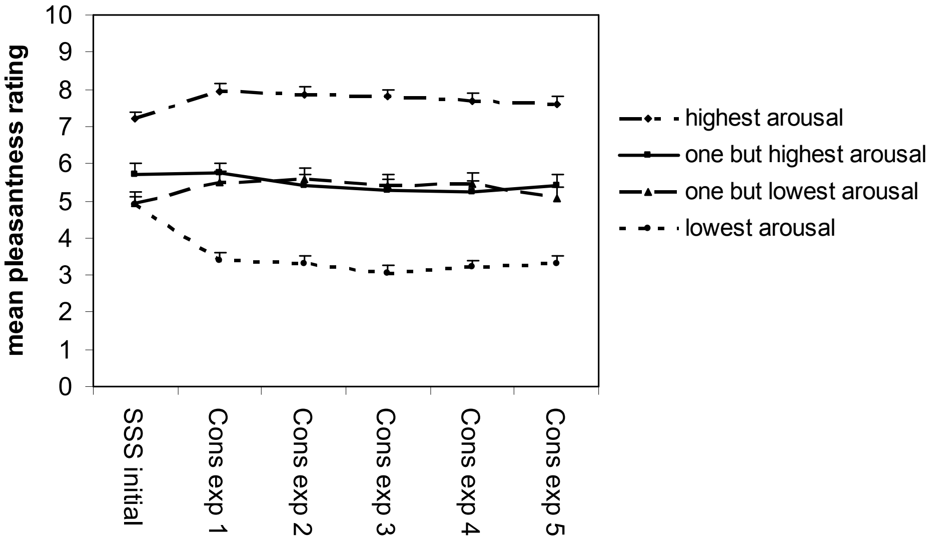

Figure 4.6: Course of pleasantness ratings (mean+SEM) of the snacks with the highest (=optimal), one but highest, one but lowest, and lowest arousal levels over time, from the SSS test until day 5 of the consumer exposure test. Pleasantness was rated on a 10cm line scale (left anchor: not at all pleasant; right anchor: extremely pleasant). The points represent the collection of different snacks that according to the participants came in 1st, 2nd, 3rd, or 4th place of arousal level.
The figure only represents the participants who preferred the snack with the highest arousal level over the other snacks (*N=31*).

Validation of SSS test as predictor of acceptance over repeated exposure

In both studies, the decrease in acceptance ratings of the products after consumption in the SSS tests did not correlate with the decrease in these ratings in consumer exposure test [soup study, pleasantness: Spearman's ϱ (*N=60*) = -0.05, *p*=0.73; snack study, pleasantness: r = 0.20; *p*=0.19, desire: r = -0.02, *p*=0.86].

Association pleasantness – intake

In both studies, there was a clear positive association between the initial acceptance ratings of the products and their *ad libitum* intake. In the soup study, the mean amounts consumed *ad libitum* in the SSS test were similar for both soups (138.5g and

121.4g, respectively for soup A and C). Initial pleasantness and intake of the soups were positively related [Spearman's ϱ (*N=60*) = 0.33, $p<0.001$]. In the snack study, participants consumed at the 5th day of the consumer exposure test most of the candy bar with chocolate and nuts (mean: 370.3 kcal; 81.7g), and least of the tea biscuit (mean: 223.0 kcal; 49.2g) and the plain chocolate (mean: 267.3 kcal; 47.1g), with the wholemeal biscuit with chocolate (mean: 330.5 kcal; 72.9g) in between [analysis in kcal: $F(3,153) = 16.5$, $p<0.001$; analysis in g: $F(3,153) = 27.1$, $p<0.001$]. There was a highly significant positive correlation between snack intake in kcal, initial pleasantness of the snacks [$r = 0.65$, $p<0.001$] and initial desire to eat the snacks [$r = 0.77$, $p<0.001$]. Snack intake was negatively correlated with initial boredom [$r = -0.51$, $p<0.001$].

DISCUSSION

The present studies investigated the effects of complexity and intensity, and the combination of these sensory properties, on the development of sensory specific satiety and on long-term acceptance of products. In addition, the results of the consumer exposure tests were compared to the results of the sensory specific satiety (SSS) tests, to determine the predictive validity of the SSS test for product acceptance over repeated exposure.

In the snack study, there was a trend for the more intense snacks (plain chocolate and candy bar with chocolate and nuts) to produce more sensory specific satiety (SSS) than the less intense snacks (wholemeal biscuit with chocolate and tea biscuit). Moreover, complexity seemed to decrease SSS; the both intense and complex snack (candy bar with chocolate and nuts) produced slightly less SSS than the intense, non-complex snack (plain chocolate). Similarly, the less intense, fairly complex snack produced somewhat less SSS than the less intense, non-complex snack. Both findings confirm the results of previous studies. Vickers and Holton (1998) found that subjects consumed less of intense tea than of weak tea. Maier, Vickers, and Inman (2007) found a positive association between the flavour intensity of potato chips and the degree of SSS. Johnson and Vickers (1992) found a slight, non-significant, trend for products with a large variety in sensory qualities (i.e. complex products) to slightly lessen SSS, compared to low variety products.

In the soup study, we could not ascertain the relations between intensity and complexity and the amount of SSS, as for both soups no sensory specific satiety developed upon consumption. An explanation for this might be that development of SSS for each soup was tested against the other, non-eaten, soups. The common chicken flavour base of the soups might have been predominant over the different characteristics of the soups, i.e. the soups might have been in each others 'band width' for SSS (Rolls, Hetherington, & Burley, 1988a, 1988b).

The findings of the snack study suggest that complexity improved sustained acceptance of the snacks, which was in accordance with earlier findings (Levy *et al.*, 2006; Hetherington, Pirie, & Nabb, 2002). Although we could not confirm this in the soup study, we demonstrated in both studies that the pleasantness of the product with the nearest to optimal arousal level (i.e. a composite of complexity and intensity) was more resistant to a decline over repeated exposure than the pleasantness of the products with the lower arousal levels (at least for individuals for whom the product with the highest arousal level was closest to their individual optimal arousal level).

These results seem to confirm Dember and Earl's (Dember and Earl, 1957) theory that stimuli that are slightly more arousing than the individual's optimal level of arousal improve long-term acceptance. However, this theory could not be tested directly, as this study was not designed to predict the position of the arousal level of the stimuli relative to the optimum (we only knew that the arousal level of the most preferred stimulus was nearer to the optimum than that of the other stimuli). Therefore, more conclusive tests of the theory of the relation between arousal level and sustained food acceptance are needed. Moreover, the calculation of arousal needs to be optimised. The calculation in the present study, i.e. as the sum of intensity and complexity, assumes that complexity and intensity influence arousal to the same extent, which may not be the case.

In the snack study, the snacks that were most resistant to a decline in acceptance over repeated exposure, i.e. the more complex snacks, were also more liked than the other snacks. Moreover, in both studies, the stimuli with the optimal arousal level were more liked than the other stimuli (this was inherent in the method of analysis we used). Thus, the possibility that the sustained acceptance of the products was due to liking rather than due to complexity / arousal cannot be excluded. Some early studies showed that an initial high acceptance of foods slowed the development of monotony (Siegel & Pilgrim, 1958; Schutz & Pilgrim, 158). In contrast, more recent studies demonstrated the opposite, i.e. that highly liked foods dropped in liking, while moderately liked foods did not (Hetherington *et al.*, 2002; Hetherington, Bell, & Rolls, 2000; Chung & Vickers, 2007). The latter findings support our idea that the sustained acceptance of the stimuli in our study was not due to a high initial liking. However, as especially the snacks not just differed in complexity and intensity, but also in other sensory qualities (e.g. in flavour and texture), it is not clear whether any of these qualities were responsible for the difference in sustained acceptance between the snacks. On the other hand, the fact that our results were in the expected direction for complexity and arousal level is encouraging for the validity of the tests of the effects of complexity and intensity on sustained acceptance. Yet, future studies that aim to test these effects should use stimuli that are equally well liked, and which differ only with respect to the sensory qualities of interest (e.g. complexity or intensity).

The idea that sensory specific satiety and long-term boredom have the same underlying mechanism, and thus that SSS can be a useful predictor for long-term product boredom, could not be verified. It might be that the short- and long-term 'boredom' effects only partially represent the same phenomenon. SSS is measured directly after consumption, and may reflect intrinsic changes in the motivation to eat the food, i.e. in appetite for the food. Conversely, long-term boredom is probably affected by a variety of factors, including cognitions about the eating situation (e.g. recency of consumption, normal consumption frequency, usual consumption occasion etc.), in addition to an intrinsic response to the sensory properties of the food. Therefore, it may reflect a general loss in interest in the food.

To measure SSS and acceptance over repeated exposure in the snack study, we kept the caloric intake of the snacks equal instead of the intake in grams, in order to make sure that a possible difference in the decrease in acceptance ratings among the snacks would not be caused by a difference in physiological satiety. Previous findings suggest, on the other hand, that acceptance ratings of foods are affected more by the amount of food that is consumed than by its energy content (Rolls, Laster, & Summerfelt, 1989; Miller, Bell, Pelkman, Peters, & Rolls, 2000). If we would have chosen to keep the amount in grams equal among the snacks, participants would have had to consume more plain chocolate than they consumed now. For SSS, this would most likely have resulted in a stronger confirmation of the finding that intensity enhances the development of SSS.

Consumption of the products till SSS seemed to have increased the acceptance ratings of the products in both studies, and to have decreased the impression of their intensity and complexity. All of these changes are in the direction that would be predicted by the effect of mere exposure on preference (e.g. Rozin & Vollmecke, 1968) and on impressions of complexity and intensity (Berlyne, 1960).

Both studies demonstrated a clear positive relation between acceptability and intake of the products. In both studies, the more complex products tended to be more pleasant than the less complex products and the *ad libitum* intake of these products tended to be higher as well. This is in accordance with previous findings (Bobroff & Kissileff, 1986; De Graaf, De Jong, & Lambers, 1999; Rolls, Van Duijvenvoorde, & Rolls, 1984; De Graaf *et al*., 2005), and suggests that intake can be used as a reliable predictor for acceptance.

In conclusion, the mechanisms underlying sensory specific satiety and acceptance over repeated exposure seem at least partially different from each other. It appears that the complexity or rather the arousal level of a product, which is a combination of intensity and complexity, drives its acceptance over repeated exposure. Products with an arousal level near (and probably slightly higher than) the optimum seem to be more resistant to a decline in acceptance upon repeated exposure than products with a lower arousal level. With respect to sensory specific satiety, intensity seems to be a key driver of SSS, while complexity seems to reduce SSS, albeit only slightly. The results of the present studies need to be repeated using stimuli that are more comparable with respect to initial liking and the sensory qualities other than complexity and intensity, and of which the position relative to the optimal arousal level has been predicted.

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5

Sensory specific satiety and intake: the difference between nibble and bar size snacks

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The present study investigated 1) whether consumption of a nibble size snack, as compared to a bar size snack, leads to more sensory specific satiety (SSS) and a lower intake, and 2) whether attention to consumption, as compared to usual consumption, leads to more SSS and a lower intake. Subjects (*N=59*) tested two snack foods which differed in size, nibbles and bars, in two consumption conditions. In the attention condition the instruction to chew the food well was given. In the control condition no such instruction was given. For each of the four SSS sessions *ad libitum* intake was measured and SSS scores were calculated. Mean intake of the nibbles was 12% lower than of the bars in the control condition, but not in the attention condition. Although non-significantly, attention to consumption tended to reduce intake of the bars, but not of the nibbles. SSS scores were slightly higher for the bars than for the nibbles. Our results suggest that a smaller food size results in a lower intake. The data do not clearly support the idea that attention to consumption decreases intake. Hypothetically consumption of small foods and attentive consumption prolong the oral sensory stimulation, which results in a lower intake.

Keywords: Sensory specific satiety; Intake; Attention; Snack size

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INTRODUCTION

From the perspective of the prevention of overconsumption it is important to identify features of foods that influence the termination of intake. A factor that may play an important role in the termination of intake of a food is the degree of *sensory specific satiety* (SSS) for that food (Hetherington, 1996; Sørensen, Møller, Flint, Martens, & Raben, 2003). This refers to a decrease in the reward derived from consumption of the food (Rolls, 1984). The phenomenon of sensory specific satiety has been widely demonstrated, both reflected by a decline in ratings of desire for the consumed food (e.g. Miller, Bell, Pelkman, Peters, & Rolls, 2000; Guinard & Brun, 1998; Maier, Vickers, & Inman, 2007; Brunstrom & Mitchell, 2006), and by a decline in the ratings of pleasantness of the consumed food (e.g. Bell, Roe, & Rolls, 2003; Johnson & Vickers, 1992; Rolls & McDermott, 1991; Rolls, Rowe, & Rolls, 1982). The decrease in reward value is only apparent for the food consumed and foods with similar sensory properties, while the reward value derived from consumption of other, less similar, alternatives remains high (Rolls, Rowe, & Rolls, 1982; Rolls, 1984). Sensory specific satiety is primarily related to the sensory stimulation accompanying consumption as opposed to the postabsorptive effects of ingesting foods (Hetherington, Rolls, & Burley, 1989).

Foods may differ in the degree of sensory specific satiety they produce. This means that of some foods the pleasure derived from consumption will decline sooner than for other foods, and therefore smaller amounts of those foods will be eaten. Guinard and Brun (1998) demonstrated that hard lunch foods produced more SSS than soft lunch foods. To consume hard foods, relatively many chewing cycles are required (Hiiemea, Heath, & Heath *et al.*, 1996), which prolongs the oral sensory stimulation. Similarly, Lavin and colleagues (Lavin, French, Ruxton, & Read, 2002) demonstrated that energy intake was lower after chewing sucrose-containing pastilles over 10 min., compared to after drinking a sucrose-containing beverage over 2 min. This may have been due to the prolonged oral sensory stimulation when chewing the pastilles compared to when drinking the beverage. The degree of sensory specific satiety for a particular food may thus be dependent on the time-span in which the food is chewed or present in the mouth, i.e. the length of oral sensory stimulation.

The length of oral sensory stimulation may be associated with the size of food, and with the degree of attention that is paid to consumption of a food. For example, Spiegel (2000) demonstrated that large foods were consumed with larger bites than small foods, and that large bites were chewed less than small bites, which reduces the oral sensory stimulation. Similarly, distraction from attention to consumption (e.g. by television viewing) probably reduces the number of chewing cycles per consumption and the oral sensory stimulation, as it has been shown to increase the ingestion rate (macaroni: Blass, Anderson, Kirkorian, Pempek, Price, & Koleini, 2006; lunch foods: Bellisle, Dalix, & Slama, 2004).

The size of a food and the degree of attention that is paid to consumption may thus affect the degree of SSS and the *ad libitum* intake. These associations were investigated in the present study. Two snack foods which differed in size, nibbles and bars, were compared in two consumption conditions, attentive consumption versus control, i.e. usual consumption. We expected that consumption of the nibble size snack, as compared to the bar size snack, would lead to more SSS, and a lower intake. We hypothesized that for both snack foods attention to consumption, as compared to usual consumption, would lead to more SSS, and a lower intake.

METHODS

Participants

Subjects were 59 adults (5 male and 54 female), aged 18-63 y (mean age=28.4 y). Most subjects were college students in the age of 18-24 y (*N=44*). The BMI range was 17.7-30.5 (mean BMI=22.3). Most subjects were normal weight (BMI between 18.5-25.0, *N=48*); 1 subject was underweight, and 10 subjects were overweight. Exclusion criteria were weight change of more than 5 kg during the last 6 months, gastrointestinal illness or illness of the thyroid gland, diabetes, allergy for any of the products used in the study, pregnancy, lactation, the use of medication with a possible effect on taste and/or appetite, and high dietary restraint (*N=13*) (Van Strien, Frijters, Bergers, & Defares, 1986). Subjects were recruited through advertisements in local newspapers and flyers. The subjects were unaware of the aim of the research.

They signed for informed consent upon participation. The study was approved by the Medical Ethical Committee of Wageningen University.

Study design

The study design was a 2×2 (snack food×consumption condition) cross-over design. The subjects thus attended 4 different sessions. Each session one of the two snacks, nibbles or bars, was served in one of the two different consumption conditions, attention or control. In the attention condition subjects were instructed to chew the snacks properly, to swallow each bite before taking the next one, and to consume the snacks until they would feel pleasantly satiated. In the control condition subjects were only instructed to consume the foods until they would feel pleasantly satiated. The order of the sessions was randomized across subjects. The design of the sessions was similar to that of previous SSS studies (e.g. Rolls, Rolls, Rowe, & Sweeney, 1981) (Figure 5.1). Each session subjects tasted a small sample of six foods, one of which was the snack food (either bar or nibble), and rated them on different motivational and hedonic measures. Subsequently, they consumed an *ad libitum* amount of the same snack food as was in the rating set. Finally, they once more tasted a small sample of the same six foods and rated them on the same measures. SSS was calculated as the decline in motivational and hedonic ratings of the consumed snack from before to after consumption relative to the decline in motivational and hedonic ratings of the other, uneaten, foods.

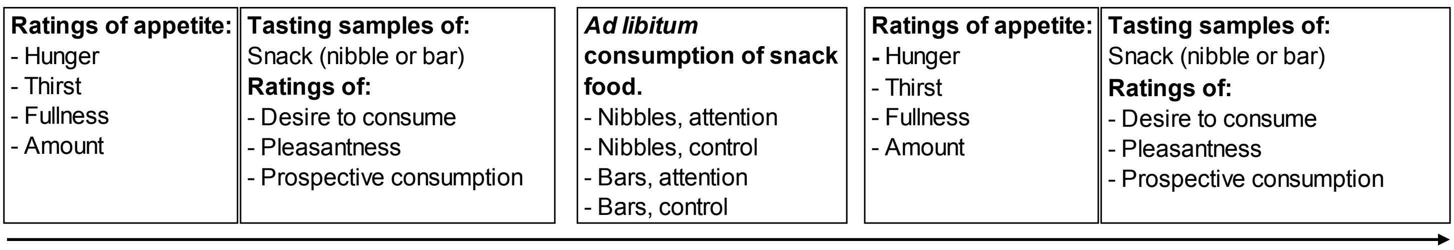

Figure 5.1: Schematic overview of each tasting session for a participant.

Foods

The snacks were biscuit based, with a chocolate-hazelnut cream filling. The snacks differed in weight and in size. The weight of one bar was 16.0 g, and its size was 9.0 x 4.0 x 1.0 cm. The weight of one nibble was 1.45 g, and its size was 2.5 x 1.5 x 1.0 cm. The energy density and the nutrient composition of the two snacks were identical (energy: 1843 kJ/100 g; protein: 11 g/100 g; fat: 17 g/100 g; carbohydrates: 63 g/100 g), and also the percentage of cream was held constant at 48% per nibble and per bar. The snacks were specifically developed for the purpose of the study.

The other five foods of the rating set (hereafter named: uneaten foods) were chosen to clearly differ from the snack foods in taste and texture. Selected foods were raw carrots (Parijse worteltjes, Albert Heijn®), half-matured cheese (Frico®), cola (Pepsi®), salty pretzels (Lorenz®), and sweetened strawberry yoghurt (Friesche Vlag®). The foods of the rating set were served in small portions in 30ml plastic cups.

Procedure

On the test days subjects came to the sensory laboratory. They were instructed to eat a normal breakfast and lunch, and not to eat or drink anything during an hour prior to the research (except for water, and tea or coffee without added milk or sugar). Subjects performed the experimental sessions in separate tasting booths. Sessions were scheduled between 9.30 and 11.30am or between 2.00 and 4.00pm on 4 days, separated by at least 48 h. As soon as subjects arrived at an experimental session they received written instructions of the procedure of the test session. Next, they rated their hunger, thirst, fullness, and 'how much food they thought they could eat' in 5 labelled categories, ranging from 'not at all' to 'extremely'. Subjects then were presented with a tray containing small samples (± 5 – 10 g) of the six foods. They were asked to taste the samples from left to right. The presentation order of the samples on the tray was randomized across subjects and across sessions. Subjects rated each sample for two motivational measures, i.e. desire to consume the food now and prospective consumption of the food, and for one hedonic measure, i.e. pleasantness. Desire and prospective consumption were rated in 5 labelled categories, anchored from 'not at all' to 'extremely' for desire, and from 'not much at all' to 'extremely much' for prospective consumption. Pleasantness was rated in 7 labelled categories, anchored from 'not at all pleasant' to 'extremely pleasant'. Subjects were instructed to rinse their mouth with water between tasting the different products. Following the evaluation of the rating set foods, subjects were given a 96.0 g serving of one of the two snacks (6 bars or 66 nibbles), together with written instructions. They were either just instructed to consume the snack until pleasantly satiated (control condition), or they received the additional consumption instructions (attention condition). When subjects had finished their plate they were served more, unless they indicated that they had enough. Subjects were instructed to record their consumption time by using a stopwatch. In order to avoid that subjects would terminate the consumption because of time reasons, they were instructed to remain in the tasting booth for at least 10 minutes. Finally, subjects repeated their hunger indices ratings (hunger, thirst, fullness, and amount), and then re-tasted and re-rated another set of the 6 food items. *Ad libitum* intake of the snacks was measured afterwards by the investigators by weighing the left-overs on the plate.

Data analyses

Data were analyzed using SPSS 12.0.1 for Windows. Results were considered statistically significant at a p-value of <0.05. Intake and ingestion rate, calculated by dividing the total intake by the consumption time, were compared between the snacks for each of the consumption conditions, and between the consumption conditions for each of the snacks. This was done by paired Student's T-tests. Additionally, the crude analyses were corrected for initial motivational and hedonic ratings using Univariate ANOVA, with the initial motivational and hedonic ratings as covariates, and participant number as a random factor to account for within-subjects variation.

For each of the experimental conditions, the decline in motivational and hedonic ratings from before to after snack consumption was compared between the snack and the uneaten foods. Therefore, change scores were calculated for the snacks and each of the uneaten foods, by subtracting the ratings before snack consumption from the ratings after consumption. The change scores of the uneaten foods were averaged for each condition. Then, the change score of the snack was compared with the mean change score of the uneaten foods, using paired Student's T-tests. Additionally, the change score of the snack was compared with the change scores of each of the uneaten foods, using ANOVA for repeated measures. LSD post-hoc analyses were used to test for pairwise differences between the foods.

Instead of one measure of SSS, three measures were used, i.e. desire to eat the food, pleasantness, and prospective consumption of the food. The distinction amongst these measures may be important as eating a food until pleasantly satiated may primarily influence the motivation to eat the food (i.e. the ratings of desire and prospective consumption) as opposed to the hedonic evaluation (i.e. the ratings of pleasantness) of the food (Mela, 2001). SSS scores were calculated in each of the experimental conditions by subtracting for each of the three SSS measures the mean change score of the uneaten foods from the change score of the eaten snack. SSS scores were compared between the snacks for each of the consumption conditions, and between the consumption conditions for each of the snacks. This was done by paired Student's T-tests. Additionally, the crude analyses were corrected for intake and the initial motivational and hedonic ratings using Univariate ANOVA. Intake and the initial motivational and hedonic ratings were added as covariates, and participant number as a random factor. Regression analyses were used to calculate the simple slopes reflecting changes in intake as a function of initial hedonic ratings, changes in SSS as a function of intake, and changes in SSS as a function of initial hedonic ratings.

RESULTS

Comparison of intake between the snacks and between the consumption conditions

Intake: The mean *ad libitum* intake of the snacks was around 40 g. Intake of the nibbles was 12% lower than of the bars in the control condition [$t(58)=2.5$, $p=0.02$], while intake was similar for the two snacks in the attention condition [$t(58)=-0.05$, $p=0.95$]

(Table 5.1). Intake of the bars tended to be lower in the attention condition than in the control condition. However, this was not statistically significant [t(58)=-1.5, p=0.13]. Intake of the nibbles was similar in both consumption conditions [t(58)=-0.6, p=0.53] (Table 5.1). Correction of the crude analyses for each of the three initial motivational and hedonic ratings (separately) did not change these associations.

Intake appeared to be positively associated with the initial motivational and hedonic ratings. On average, an increase of one point in the initial ratings of desire to eat, pleasantness, and prospective consumption increased intake with 10.8 g, 9.5 g, and 13.5 g, respectively [all p<0.001]. Thus, participants consumed more of the snacks when they liked them better.

Ingestion rate: In both consumption conditions, the mean ingestion rate of the bars was significantly higher than the mean ingestion rate of the nibbles [attention: t(57)=3.8, p<0.001; control: t(56)=5.4, p<0.001] (Table 5.1). The mean ingestion rate of the nibbles was significantly lower in the attention condition compared to the control condition [t(57)=-3.7, p<0.001]. For the bars, a similar pattern could be observed, although this was non-significant [t(57)=-1.3, p=0.20] (Table 5.1).

Table 5.1: Intake (g) and ingestion rate (g/min) (mean ± SEM) of the snacks in each of the consumption conditions (left: attention condition; right: control condition). The snacks were served in portions of 96.0g.

	Control condition		Attention condition	
	Nibbles	Bars	Nibbles	Bars
Intake (g)	38.4 ± 3.8	43.6 ± 3.9 *	39.8 ± 3.7	39.7 ± 3.5
Ingestion rate (g/min)	8.0 ± 0.4	9.5 ±0.4 *	6.6 ± 0.3 †	8.9 ± 0.6 *

* Within rows, means are significantly different from the nibbles, in the same consumption condition [p<0.05].

† Within rows, means are significantly different from the control condition, for the same snack [p<0.05].

Initial motivational and hedonic ratings

The initial motivational and hedonic ratings, averaged over the experimental conditions, did not differ between the nibbles and the bars. Comparison of these ratings amongst the snacks and each of the uneaten foods revealed that they tended to be highest for the strawberry yoghurt, followed by the carrot, cheese, cola and pretzel, and lowest for the nibbles and bars. For reference, see Table 5.2.

Table 5.2: Initial motivational and hedonic ratings (mean) of the each of the foods of the ratings set, averaged over the experimental conditions (*N=59*).

	Cola	Cheese	Pretzel	Carrot	Yoghurt	Bars	Nibbles
Desire to eat†	3.0 c,d	2.8 b	2.5 a,b	2.8 c	3.3 d	2.4 a	2.4 a
Pleasantness‡	4.5 a,b	4.6 b,c,d	4.8 c,d	4.9 d	5.3 e	4.3 a,b	4.2 a
Prosp. cons. of food†	2.3 a,b	2.2 a,b	2.3 a,b	2.4 b	2.9 c	2.0 a	2.1 a

† rated in 5 labelled categories, anchored from 'not at all' to 'extremely' for desire to eat, and 'not at all much' to 'extremely much' for prospective consumption of the food.
‡ rated in 7 labelled categories, anchored from 'not at all pleasant' to 'extremely pleasant'.
a,b,c,d Within rows, different letters indicate significant differences [$p<0.05$].

Decline in motivational and hedonic ratings after consumption of the snacks

Comparison between the snacks and the average of the uneaten foods: The motivational and hedonic ratings of both snacks tended to decline more after snack consumption than these ratings averaged over the uneaten foods. When the bars were consumed, the difference between the snack and the uneaten foods was statistically significant for all three ratings in both consumption conditions [$t(58) \leq -2.64$, $p \leq 0.01$]. When the nibbles were consumed, this difference was statistically significant in both consumption conditions for the ratings of desire to eat and prospective consumption of the food [$t(58) \leq -2.20$, $p \leq 0.03$], but not for the ratings of pleasantness, in none of the consumption conditions [$t(58) \geq -1.68$, $p \geq 0.10$] (Table 5.3). This means that SSS developed for both snacks, in each of the consumption conditions, though not statistically significantly for the nibbles when SSS was measured by the pleasantness ratings.

Comparison between the snacks and each of the uneaten foods: When comparing the decline in motivational and hedonic ratings of the snacks after snack consumption with the decline of each of the uneaten foods separately, it appeared that the decline of yoghurt tended to be similar to the decline of the snacks [*p*-values for difference of decline in desire between yoghurt and snack: bars-attention=0.16; bars-control=0.05; nibbles-attention=0.26, nibbles-control=0.83]. For all the other uneaten foods the drop in motivational and hedonic ratings was significantly smaller than the drop of the snacks.

Comparison of SSS between the snacks, and between the consumption conditions

The SSS scores (= decline in motivational and hedonic ratings of the snack – average decline in motivational and hedonic ratings of the uneaten foods) were compared between the nibbles and the bars, and between the two consumption conditions. The SSS scores of desire to eat were comparable between the snacks in the attention condition [$t(58)=-0.3$, $p=0.74$], but slightly higher for the bars than for the nibbles in the control condition [$t(58)=1.9$, $p=0.06$, n.s.] (Table 5.3). Correction for intake and initial desire ratings reduced this association [$p=0.14$]. The SSS scores of pleasantness were comparable between the snacks in the control condition [$t(58)=0.9$, $p=0.38$], but tended to be higher for the bars than for the nibbles in the attention condition [$t(58)=2.0$, $p=0.06$, n.s.] (Table 5.3). Also this association was reduced after correction of the analysis for intake and initial pleasantness ratings [$p=0.18$]. The SSS scores of prospective product consumption ratings were comparable between the snacks [$p\geq0.63$]. All three SSS measures (desire, pleasantness, and prospective consumption of the food) were comparable between the consumption conditions, for the nibbles [$p\geq0.35$], as well as for the bars [$p\geq0.08$].

Table 5.3: Changes in motivational and hedonic ratings from before to after snack consumption, and the associated SSS scores (mean ± SEM)

	Control condition			Attention condition		
	Change in eaten food [a]	**Change in uneaten foods [b]**	**Difference (SSS score)**	**Change in eaten food [a]**	**Change in uneaten foods [b]**	**Difference (SSS score)**
Desire to eat						
Nibbles	-0.8 ± 0.1	-0.5 ± 0.1 *	-0.3 ± 0.1	-0.9 ± 0.1	-0.6 ± 0.1 *	-0.3 ± 0.1
Bars	-1.1 ± 0.1	-0.5 ± 0.1 *	-0.6 ± 0.1	-0.9 ± 0.1	-0.5 ± 0.5 *	-0.4 ± 0.1
Pleasantness						
Nibbles	-0.5 ± 0.1	-0.3 ± 0.03	-0.2 ± 0.1	-0.4 ± 0.1	-0.3 ± 0.1	-0.1 ± 0.1
Bars	-0.5 ± 0.1	-0.2 ± 0.04 *	-0.3 ± 0.1	-0.5 ± 0.1	-0.2 ± 0.04 *	-0.3 ± 0.1
Prosp. cons. of food						
Nibbles	-0.8 ± 0.1	-0.5 ± 0.1 *	-0.3 ± 0.1	-0.9 ± 0.1	-0.6 ± 0.1 *	-0.3 ± 0.1
Bars	-0.9 ± 0.1	-0.5 ± 0.1 *	-0.4 ± 0.1	-0.8 ± 0.1	-0.4 ± 0.1 *	-0.4 ± 0.1

[a] Change in ratings for the eaten food (nibbles or bars).

[b] Average change in ratings for five uneaten foods (raw carrots, half-matured cheese, cola, salty pretzels, and sweetened strawberry yoghurt).

* Within rows, mean ratings of change of the uneaten foods are significantly different from the eaten foods, in the same consumption condition [p<0.05].

All three SSS measures were positively associated with the initial motivational and hedonic ratings as well as intake. Thus, SSS scores were higher when participants liked the snacks better, and when they consumed more of the snacks. On average, an increase in the initial ratings of desire, pleasantness, and prospective consumption of one point increased the corresponding SSS score with 0.7, 0.3, and 0.8, respectively [all p<0.001]. And an increase in intake of 10 g increased the SSS scores of desire, pleasantness, and prospective consumption with 0.06 [p=0.01], 0.04 [p=0.04], and 0.09 [p<0.001], respectively.

DISCUSSION

In line with our expectations, *ad libitum* intake of the nibbles was lower than of the bars in the control condition. Also the ingestion rate (g/min) of the nibbles was lower. As eating foods with smaller bites reduces the ingestion rate (Spiegel, Kaplan, Tomassini, & Stellar, 1993), this supports the idea that participants consumed the nibbles with smaller bites than the bars. Then, the results of our study confirm the assumption in behavioural theory that when bite size is smaller, the amount consumed is lower (Ferster, Nurnberger, & Levitt, 1962; Stuart & Davis, 1972). Also behaviour therapists have recommended that obese people try to take smaller bites, because it would help them to be satisfied with less food (Brownell & Wadden, 1999; Jordan & Levitz, 1975). Moreover, some previous empirical tests have demonstrated a positive association between bite size and food intake in adults (meals: Walden, Martin, Ortego, Ryan, & Williamson, 2004) and in preschool-aged children (entreés: Orlet-Fisher, Rolls, & Birch, 2003). However, not all studies could confirm this: although Spiegel and colleagues demonstrated a positive association between bite size of sandwiches and ingestion rate, this did not affect total intake (Spiegel *et al.*, 1993).

SSS scores tended to be higher after consumption of the bars than after consumption of the nibbles. Given the higher intake of the bars than of the nibbles this was surprising, as previous studies suggested that SSS could reduce food intake (e.g. Sørensen *et al.*, 2003). However, the difference in SSS scores may have been confounded by a difference in intake between the snacks. That is, that as a result of the higher intake of the bars, the post-consumption motivational and hedonic ratings of the bars may have been lower, and their SSS scores therefore higher. This was supported by the positive association between intake of the snacks and SSS scores. Similarly, in studies in which the food volume was controlled, more SSS after consumption of higher volumes of food was demonstrated (Bell, Roe, & Rolls, 2003; Bell, Thorwart, & Rolls, 1998). We therefore recommend standardizing the food intake, when aiming to use SSS scores as predictors of satiety. To compare sensory specific satiety between foods, at least within the same category, comparing intake may be more reliable than comparing SSS scores.

Attention to consumption did not significantly reduce intake of the snacks or increase SSS scores, compared to usual consumption. Therefore our results suggest that paying special attention to consumption does not considerably affect intake or SSS scores. In contrast, evidence from previous studies supports that attention to consumption decreases food intake. For example, Wansink and Park (2001) demonstrated that intake of popcorn during a movie was limited in subjects who had paid attention to the taste of the popcorn during consumption. Poothullil (2005) showed that intake of beverages was less when subjects were instructed to consume until satisfied based on taste than when instructed to consume until satisfied based on stomach feelings. Intake was often found to be enhanced when subjects' attention was distracted from consumption (beverages: Poothullil, 2005; Bellisle & Dalix, 2001; Stroebele & De Castro, 2004 (review); cereals: Poothullil, 2002). Brunstrom and Mitchell (2006) found that distraction by a computer game attenuated the development of sensory specific satiety for cakes. A possible explanation for the divergent results of our study is that the consumption procedure in the attention condition (chewing well, swallowing each bite before taking the next one) resembled normal consumption for many participants. Moreover, for subjects who attended an attention condition before a control condition, recalling the procedure of the attention condition, may have resulted in consumption of the snacks in like manner in the control condition. However, the lower ingestion rate of the snacks in the attention condition compared to the control condition supports that subjects changed their way of eating as a result of the attention instructions. Perhaps the attention instructions in our study mainly resulted in a prolonged interval between bites rather than in an increased number of chews per bite, while the manipulations of attention or distraction in the other studies affected the number of chews per bite. The number of chews per bite affects the length of oral sensory stimulation, while the interval between bites affects the ingestion rate, but not the length of oral sensory stimulation per consumption.

Probably, a reduced oral sensory stimulation, due to a larger bite size, can explain the higher intake of the bars compared to the nibbles. The same phenomenon might explain the disproportionate energy intake and the low satiety from caloric beverages as compared to solid foods (Hulshof, De Graaf, & Weststrate, 1993; Tournier & Loius-Sylvestre, 1991; DiMeglio & Mattes, 2000; De Castro, 1993). A brief oral sensory stimulation might also explain the lack of sensitivity to calories and the resulting excessive energy intake from fast food (Bowman & Vinyard, 2004). Meals in fast food restaurants are consumed faster, thus probably with a shorter oral sensory stimulation, than other meals (Bell & Pliner, 2003).

A limitation of the present study was, however, that the length of oral sensory stimulation was not directly measured and that bite size was unconstrained. Therefore, just like the lower ingestion rate of the snacks in the attention condition compared to the control condition, the lower ingestion rate of the nibbles compared to the bars may have been caused by a prolonged interval between bites instead of by consumption with smaller bites. Actually, the length of oral sensory stimulation may thus have been equal between the nibbles and the bars. Another phenomenon than a prolonged oral sensory stimulation may therefore also explain the lower intake of the nibbles than of the bars. For example, participants may have underestimated the serving size of the bars compared to the nibbles. Visual underestimation of the portion size has been shown to lead to over-consumption (Wansink, Painter, & North, 2005). It has, for example, been shown that people consistently underestimate and over-consume the amount of liquid they pour into a short, wide drinking glass, compared with tall, narrow glasses that hold the same volume (Wansink & Van Ittersum, 2003).

Initial hedonic ratings were positively associated with the development of SSS. Previous studies demonstrated the opposite (Johnson & Vickers, 1992) or found no association between SSS and initial liking (Snoek, Huntjens, Van Gemert, De Graaf, & Weenen, 2004; Rolls, Rowe, Rolls, Kingstone, Megson, & Gunary 1981). Our finding might, however, be explained by the dependence of SSS measures on hedonic scale scores. The higher the initial hedonic ratings on a rating scale, the more these ratings can possibly drop after consumption, thus the more SSS can possibly be measured. Therefore, SSS scores should only be used when the mean initial hedonic ratings of all test foods are sufficiently high (to allow a drop after consumption) and comparable.

After consumption of the snacks the motivational and hedonic ratings of (uneaten) yoghurt dropped considerably compared to the other uneaten foods. This was unexpected, as SSS usually only extends to foods with similar sensory features (e.g. Guinard & Brun, 1998). The sensory features of yoghurt were clearly different from the sensory features of the snacks, except for sweetness. A possible explanation of this may however again be the high initial hedonic ratings of the yoghurt, which allowed the hedonic ratings to drop more that those of the other, less liked, uneaten foods. It is also possible that the similarity in sweetness between the snacks and the yoghurt was sufficient for a decrease in desire for the snacks to extend to a decrease in desire for yoghurt (see also De Graaf, Schreurs, & Blauw, 1993).

Most participants were female college students with a healthy body weight. Smeets and colleagues (Smeets, De Graaf, Stafleu, Van Osch, Nievelstein, & Van der Grond, 2006) suggested that there may be differences in the patterns of SSS between genders, as they found differences in brain activation between men and women in response to satiation. Moreover, some studies suggested that the extent of sensory specific satiety may differ between age groups (Rolls & McDermott, 1991) and between normal weight and obese people (Epstein, Paluch, & Coleman, 1996). Therefore, it would be sensible to extend this study to other populations.

Although the results suggest that consumption of nibble size snacks instead of bar size snacks might facilitate the limitation of snack intake, it remains to be investigated whether this result can be extended to a naturalistic setting, in which besides sensory cues also cognitive control is required to terminate intake (Kral, 2006). Snacks are foods that are typically consumed when cognitive control of food intake is limited, for example when distracted by other activities such as work or watching television (Wansink, 2004). In these situations, cognitively monitoring consumption may be easier for bar size snacks than for nibble size snacks, as the former are more easily considered as a food unit, finishing of which seems to inhibit further consumption (Geier, Rozin, & Doros, 2006).

In general, the results suggest that a small food size or a small bite size may reduce food intake. Our data do not clearly support the idea that attention to consumption decreases intake. Consumption of small foods and possibly also attentive consumption may prolong the oral sensory stimulation, which reduces intake by an accelerated development of sensory specific satiety. To reinforce this, the results of this study should be replicated in a study in which bite size is constrained, in which is observed how paying special attention to consumption affects people's eating style (i.e. increasing the number of chews per bite or the interval between bites), and in which the length of oral sensory stimulation is measured.

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6

Sip size of orangeade: effect on intake and sensory specific satiety

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The present study examined 1) whether the length of oral sensory stimulation of orangeades is associated with sensory specific satiety (SSS) and orangeade intake, and 2) whether the degree of sensory specific satiety is comparable between orangeade sweetened with artificial sweeteners (virtually no energy, 'no-energy') and sweetened with sucrose (energy-containing, 'regular-energy'). In a cross-over design, subjects (*N=53*) tested no-energy and regular-energy orangeade, with large sips (20 g / sip) and small sips (5 g / sip). Overall rate of ingestion was constant (150 g/ min). In the small sip condition, mean intake of the no-energy orangeade was 338 g, while mean intake of the regular-energy orangeade was 352 g. In the large sip condition, mean intake of the no-energy orangeade was 405 g, while mean intake of the regular-energy orangeade was 493 g. Mean intake of both types of orangeade was thus lower when consumed with small sips then when consumed with large sips [both $p<0.001$]. Moreover, in the large sip condition, mean intake of the no-energy orangeade was lower than of the regular-energy orangeade [$p=0.02$]. In the small sip condition, mean intake was comparable between the two types of orangeade. Yet, SSS scores of desire were higher for the no-energy orangeade than for the regular-energy orangeade [$p=0.01$]. Our results suggest that a smaller sip size, i.e. a prolonged oral sensory stimulation per consumption, results in a lower intake, possibly due to an accelerated development of sensory specific satiety. Moreover, regular-energy orangeade may produce less sensory specific satiety than no-energy orangeade, although evidence of previous studies does not support this. Possible explanations and implications of both findings are discussed.

Keywords: Sensory specific satiety; Intake; Sip size; Energy content

Manuscript in preparation

The study described in this chapter is part of a larger study, which consists of two parts. In the one part, behavioural measures are used to assess sensory specific satiety, i.e. food intake and subjective scores of pleasantness and desire to eat. In the other part, sensory specific satiety is assessed by a neurobiological measure, i.e. brain activity (measured with fMRI scans). For publication, the results of both parts will be combined in one manuscript. However, as the data collection of the neurobiological part was still ongoing when this thesis was submitted, in this chapter only the results of the behavioural measure will be described. Therefore, the conclusions that are drawn here are only preliminary.

INTRODUCTION

The regulation of food intake is governed by external/environmental factors and by internal factors. Important external factors are portion size, social context, sensory cues, and distraction (as reviewed by Wansink, 2004). One important internal factor is the degree of sensory specific satiety, which refers to the decrease in the reward value of the taste of food during consumption (Hetherington, 1996). If sensory specific satiety occurs, one is not satiated per se, but satiated to the sensory characteristics of the specific food that was consumed. In the brain of primates (among which humans) sensory specific satiety is associated with a decrease in the responses of specific neurons in the orbitofrontal cortex (OFC) to the food eaten to satiety, while much less of a decrease occurs in responses to other foods not eaten to satiety (Rolls, Murzi, & Yaxley, Thorpe, & Simpson, 1986; Rolls, Sienkiewicz, & Yaxley, 1989). The decrease of the responses of these neurons has been shown to correlate with the decrease in subjective pleasantness when a food is eaten to satiety (Kringelbach, O'Doherty, Rolls, Andrews, 2003).

One feature that has been suggested to influence the degree of sensory specific satiety (SSS) for a food is the eating rate by which food is consumed. Early studies showed a positive association between eating rate and intake of liquid and solid foods (Shaw, 1973; Jordan, 1969; Spiegel & Jordan, 1978; Kaplan, 1980). More recent experimental tests of the association between eating rate and food intake have yielded conflicting results. They demonstrated either a positive association (Blass, Anderson, Kirkorian, Pempek, Price, & Koleini, 2006; Fisher, Rolls, & Birch, 2003), no association (Spiegel, Kaplan, Tomassine, & Stellar, 1993), or an inverse association (Yeomans, Gray, Mitchell, & True, 1997).

The studies described used different methods to modify eating rate, which each differentially affect the length of oral sensory stimulation by the food, i.e. the time-span within which the food is present in the mouth (e.g. pauses between bites decrease both eating rate and oral sensory stimulation, while small bites decrease eating rate but increase oral sensory stimulation). In fact, the degree of SSS may be influenced by the length of oral sensory stimulation rather than by the eating rate; the longer the oral sensory stimulation, the higher the degree of SSS and the lower the intake. A plausible explanation is that the more prolonged the oral sensory stimulation by food, the more intense the perception of its sensory characteristics.

Food consumption with small bites has been shown to result in a low amount ingested per chew (Spiegel *et al*., 1993; Spiegel, 2000), while milk consumption with small sips has been shown to result in a low amount ingested per swallow (German, Crompton, Owerkowicz, & Thexton, 2004). Therefore, food consumption with small bites or sips increases the length of oral sensory stimulation per consumption.

Another factor that potentially influences SSS is the energy content of food. Although some studies showed that the degree of SSS increased when the energy content/amount of solid foods ingested got higher (De Graaf, Schreurs, & Blauw, 1993; Johnson & Vickers, 1993), studies that dissociated the sensory properties of fat or sugar from the energy provided by the stimulus, while matching the stimuli for taste and texture, found that the degree of SSS did not depend on the energy content of the food (orange jello (sweet): Rolls, Hetherington, & Burley, 1988; jello and pudding (sweet): Rolls, Laster, & Summerfelt, 1989; chips (fat): Miller, Hammer, Peters, & Rolls, 1996; chips (fat): Miller, Bell, Pelkman, Peters, & Rolls, 2000.

The present study tested the hypotheses that 1) consumption of orangeade with small sips leads to a high degree of sensory specific satiety (SSS), and a low intake, and that 2) the degree of SSS and the *ad libitum* weight consumed are not affected by the energy content of similarly sweet orangeades.

METHODS

Participants

Subjects were 53 healthy adults (21 male, 32 female), aged 18-29 (mean age=21.9). The mean BMI was 21.5 (SD=1.7). All subjects were soft drink consumers (at least 1 day/month). Subjects were recruited from a database of people interested in taking part in trials from the division of Human Nutrition of Wageningen University. A prescreening questionnaire was performed by eligible subjects to confirm that they were normal weight (BMI between 18.5 and 25.0), their weight was stable (no weight change of more than 5kg during the last 6 months), did not smoke, did not have a gastrointestinal illness, an illness of the thyroid gland or diabetes, did not have a food allergy, were not pregnant or lactating, did not use medication likely to affect taste or appetite, were not highly dietary restraint (Van Strien, 2002), and were regular consumers of soft drinks (at least 1 day/month). Subjects were naïve to the aim of the research and blinded for the treatments. They provided informed consent and were reimbursed for participation. The protocol of the study was approved by the Medical Ethical Committee of Wageningen University.

Study design

The study design was a 2x2 (orangeade x sip size condition) cross-over design. Each session, one of two types of orangeade, regular-energy or no-energy orangeade, was served, in one of two sip size conditions, large or small sips. The regular-energy orangeade was sweetened with sucrose, while the no-energy orangeade was sweetened with synthetic sweeteners. In the large sip condition the oral sensory stimulation per consumption was low; large sips (20 g/sip) were delivered at a high rate (600 g/min) for 2 s, and with large intervals between sips (6 s). In the small sip condition the oral sensory stimulation per consumption was higher; small sips (5 g/sip) were delivered at a low rate (300 g/min) for 1 s, and with small intervals between sips (1 s). The orangeades were consumed through a tube that was connected to a peristaltic pump, whereby the sip size, the delivery rate, and the interval between the sips were controlled. **The ingestion rate was held constant at 150 g/min for both conditions**. A pilot study was performed in a similar group of participants (*N=10*) to ensure that subjects perceived a clear difference in the length of oral sensory stimulation between the two sip size conditions, while it was reasonably pleasant to consume the orangeades in both conditions.

The design of the study was similar to previous SSS studies (e.g. Rolls, Rolls, Rowe, & Sweeney, 1981). During each session, subjects first tasted small samples (±15 g) of three stimuli, milk, tomato juice, and one of the two orangeades. They rated these stimuli on four measures: two measures of wanting, i.e. desire to eat and prospective consumption, one measure of liking, i.e. pleasantness, and sweetness intensity.

Subsequently, they consumed until pleasantly satiated an *ad libitum* amount of the same orangeade as was in the tasting set, in one of the two sip size conditions. Finally, they once more tasted small samples of the same three stimuli and rated them on the same four measures (Figure 6.1).

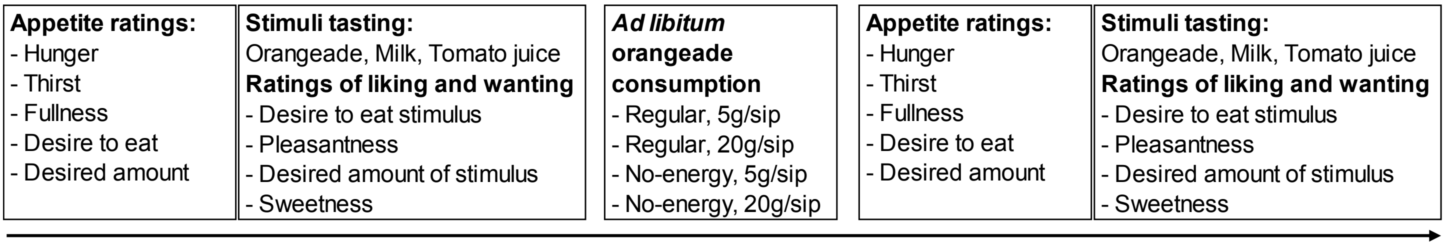

Figure 6.1: Schematic overview of the design of each of the 4 experimental sessions for a subject. The orangeade *ad libitum* consumed was either no-energy or regular-energy orangeade, and was either consumed with small (5g) or with large (20g) sips.

Stimuli

The orangeades were prepared from orange flavoured syrups. These were diluted with water (1g : 5g). The syrups were specifically developed for the purpose of the study by United Soft Drinks (Utrecht, The Netherlands), and were matched for sweetness, taste, and appearance. One of the syrups was sweetened with sucrose (per 100g orangeade: 10.4 g sucrose, 177 kJ), the other syrup was sweetened with a combination of synthetic sweeteners (per 100g orangeade: aspartame 0.011g, acesulfame k 0.011g, natriumcyclamate 0.0058g, sodiumsaccharine 0.0015g, ± 0 kJ).

The other two stimuli of the rating set were chosen to clearly differ in taste from the orangeades. These stimuli were tomato juice (Appelsientje zontomaat, Riedel®), and sterilized semi-skimmed milk (Langlekker, Friesche Vlag®). All stimuli were served at room temperature (Table 6.1).

Procedure

On the test days subjects came to the sensory laboratory. They were instructed to eat a normal breakfast and lunch, and not to eat anything during two hours prior to the research (except for water, and tea or coffee without added milk or sugar).

The study was performed in tasting booths. As soon as subjects arrived at a test session they received oral and written instructions of the procedure of the test session. Next, they completed an appetite questionnaire of 5 items (hunger, thirst, fullness, desire to eat, desired amount to eat). The items were rated on 9-point scales, ranging from 'not at all' to 'extremely'. In order to determine regular sip size, subjects were asked to drink exactly 3 sips of water. Subsequently, subjects were presented with a tray containing the three stimuli. They were asked to taste and rate the stimuli from left to right. The presentation order of the samples on the tray was randomized across subjects and across sessions. Subjects evaluated each stimulus in terms of desire to consume the stimulus, pleasantness, prospective consumption, and perceived sweetness intensity. These items were also rated on 9-point scales, from 'not at all' to 'extremely'. Subjects were instructed to rinse their mouth with water between tasting the different stimuli.

Next, subjects were instructed to take the tip of the tube with orangeade in their mouth, and to start the pump. This started the delivery of orangeade. They were instructed to consume the orangeade until pleasantly satiated. They were allowed to stop and re-start the pump whenever they wanted. Subjects were blind to the amount they consumed, as they could not see the orangeade reservoir. To avoid that subjects would terminate the consumption because of time reasons, the time for consumption was held constant at 10 minutes for all participants. After 10 minutes, they repeated completion of the appetite questionnaire, and subsequently the same tasting and rating procedure as before consumption of the orangeade.

Data analysis

Data-analyses were performed using SPSS 12.0.1. Effects were considered statistically significant at a value of $p<0.05$.

For data-analysis subjects' normal soft drink consumption was categorized in three categories: 1) regular-energy soft drink consumers: indicated to consume regular-energy soft drinks more often than no-energy soft drinks (37%); 2) both regular-energy and no-energy soft drink consumers: indicated to consume regular-energy and no-energy soft drinks equally often (28%); 3) no-energy soft drink consumers: indicated to consume no-energy soft drinks more often than regular-energy soft drinks (35%). The average sip size of each subject was categorized into one of two categories, 1) large (≥23.3g) or 2) small (<23.3g), on the basis of a median split of the normal sip size of water.

The *ad libitum* intake was compared between the two sip size conditions by paired T-tests for each of the two orangeades. Effect modification by gender and normal sip size was tested through the repeated measures procedure of the general linear model (GLM).

The *ad libitum* intake was compared between the two types of orangeade by paired T-tests for each of the sip size conditions. Effect modification by gender and normal soft drink consumer type was tested through the repeated measures procedure of the GLM.

Initial appetite ratings were compared across the four experimental conditions by the repeated measures procedure of the GLM, for each of the 5 ratings. Changes in appetite ratings were compared between the sip size conditions (for each of the orangeade types) and between the orangeade types (for each of the sip size conditions) by paired T-tests.

Initial ratings of wanting, liking, and perceived sweetness, averaged over the experimental conditions, were compared across each of the orangeades and each of the uneaten stimuli (milk and tomato juice) through the repeated measures procedure of GLM, followed by LSD multiple comparisons procedures. Gender and normal soft drink consumer type were included in the models to test for possible effect modification.

To test whether the ratings of sweetness of the orangeades had changed after orangeade consumption for each of the four experimental conditions the mean rating of change (i.e. post-consumption rating – pre-consumption rating) was compared to 0 by unpaired T-tests.

To confirm that the ratings of wanting and liking of the consumed orangeades had declined more after consumption than the ratings of wanting and liking of the non-consumed stimuli (i.e. that sensory specific satiety had developed), the ratings of change in wanting and liking were compared between the consumed orangeade and each of the non-consumed stimuli (milk and tomato juice), for each of the four experimental conditions. This was done by the repeated measures procedure of the GLM, followed by LSD multiple comparisons procedures.

For each of the four experimental conditions three measures of SSS were calculated: SSS measured by desire, SSS measured by pleasantness, and SSS measured by prospective consumption. Each of these SSS measures was calculated by subtracting for the particular measure the rating of change (i.e. post-consumption rating – pre-consumption rating) of the consumed orangeade from the corresponding rating of change averaged over the non-consumed stimuli (milk and tomato juice). The degree of SSS of the orangeades was compared between the two sip size conditions and between the two types of orangeade, using the same procedures as to compare the *ad libitum* intake of the orangeades between the two sip size conditions and between the two types of orangeade (for each of the three SSS measures).

RESULTS

None of the results differed between genders or between those who normally consume beverages with small vs. large sips. Therefore, the results for the models that included these variables will not be shown. The association between SSS measured by ratings of desire and orangeade type was different for regular-energy and no-energy soft drink consumers. Hence, just for that outcome the model including normal soft drink consumer type will be shown.

Intake

The *ad libitum* intake (in g) of both orangeades was lower when consumed with small sips than when consumed with large sips. For the regular-energy orangeade, the mean intake was 141 g (29%) lower [t(49)=4.5, $p<0.001$], while for the no-energy orangeade the mean intake was 66 g (16%) lower when consumed with small sips [t(45)=3.7, $p<0.001$] (Figure 6.2).

In the small sip condition intake (in g) was comparable between the regular-energy and the no-energy orangeade. In the large sip condition, however, the average weight consumed was 88 g (18%) lower for the no-energy than for the regular-energy orangeade [t(49)=3.3, $p=0.02$] (Figure 6.2).

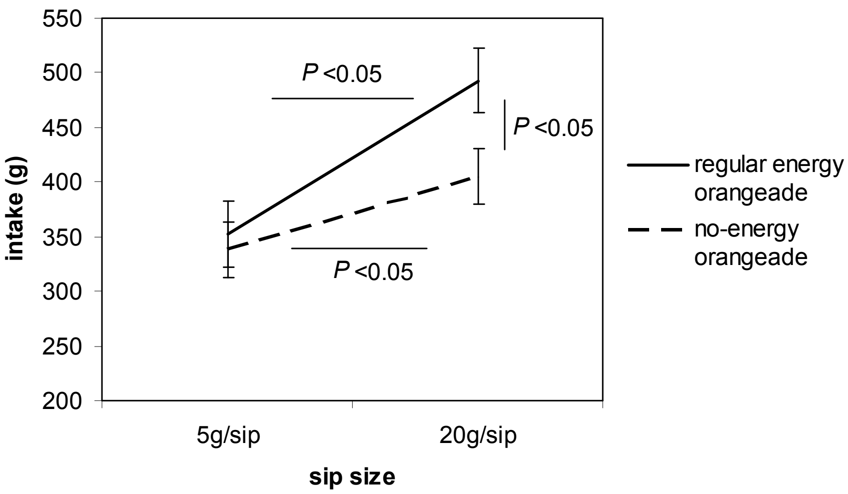

Figure 6.2: Ad libitum intake (g) of the two types of orangeade in the two sip size conditions.

Initial ratings of wanting, liking and sweetness

The initial ratings of wanting, liking and perceived sweetness (averaged over the experimental conditions) were comparable between the two orangeade types, and higher for the orangeades that for the milk and the tomato juice (Table 6.1).

Table 6.1: Initial ratings of wanting and liking, and initial ratings of sweetness (mean (SD)) of the samples, averaged over the experimental conditions.

	Regular-energy orangeade	No-energy orangeade	Tomato Juice	Milk	F-value*	*P*
Initial desire	6.2 (1.7)[b]	6.0 (1.5)[b]	4.0 (1.9)[a]	4.1 (1.8)[a]	33.0	<0.001
Initial pleasantness	6.4 (1.4)[b]	6.2 (1.2)[b]	4.3 (2.0)[a]	4.8 (2.0)[a]	16.7	<0.001
Initial prospective consumption	5.4 (1.4)[b]	5.4 (1.5)[b]	3.4 (1.8)[a]	3.8 (1.8)[a]	28.4	<0.001
Initial sweetness	6.8 (1.1)[b]	6.9 (1.0)[b]	3.9 (1.6)[a]	3.5 (1.4)[a]	141.6	<0.001

Ratings from a 9-point scale anchored from 'not at all desire/pleasant/much/sweet' at the left end to 'extremely desire/pleasant/much/sweet' at the right end.

[a,b] Numbers within a row having lower case letter superscripts in common do not differ significantly [$p<0.05$].

* F-value from the ANOVA comparing the initial subjective ratings for each stimulus. All tests have 3,156 degrees of freedom.

Sensory specific satiety

Table 6.2 shows that sensory specific satiety developed for each of the orangeades in each of the sip size conditions, except for the regular-energy orangeade in the 5g/sip condition when SSS was measured by the ratings of pleasantness.

For both types of orangeade, the degree of sensory specific satiety was comparable between the two sip sizes, for each of the SSS measures (Figure 6.3).

In the 5g/sip condition, the no-energy orangeade generated more SSS, as measured by the ratings of desire, than the regular-energy orangeade [p=0.01]. A significant effect was found for the orangeade type x normal soft drink consumer type interaction [p=0.05], which refers to the notion that this was specifically the case for the no-energy soft drink consumers, while for the regular-energy soft drink consumers both types of orangeade generated a comparable degree of SSS. The other measures of SSS were in both sip size conditions comparable between the two types of orangeade (Figure 6.3).

Table 6.2: Decline in ratings of wanting (desire and prospective consumption) and liking (pleasantness) (mean (SD)) of orangeade and the two non-consumed samples after *ad libitum* consumption of orangeade in each of the four different experimental conditions.

	Orangeade	Tomato Juice	Milk	F-value‡	*P*
Desire					
Regular-energy 5g/sip	-2.5 (1.8)[b]	-1.2 (1.4)[a]	-0.9 (1.7)[a]	13.8	<0.001
Regular-energy 20g/sip	-3.2 (1.6)[b]	-1.1 (1.7)[a]	-1.2 (1.6)[a]	28.5	<0.001
No-energy 5g/sip	-3.3 (1.3)[b]	-1.0 (1.7)[a]	-0.8 (1.7)[a]	46.3	<0.001
No-energy 20g/sip	-2.8 (1.7)[b]	-0.9 (1.4)[a]	-1.1 (1.7)[a]	23.0	<0.001
Prospective consumption					
Regular-energy 5g/sip	-2.8 (1.8)[b]	-1.2 (1.5)[a]	-1.3 (1.5)[a]	17.9	<0.001
Regular-energy 20g/sip	-3.2 (1.4)[b]	-1.0 (1.7)[a]	-1.4 (1.3)[a]	39.0	<0.001
No-energy 5g/sip	-3.1 (1.5)[b]	-1.1 (1.6)[a]	-1.0 (1.2)[a]	36.7	<0.001
No-energy 20g/sip	-3.0 (1.5)[b]	-0.9 (1.8)[a]	-1.5 (1.7)[a]	27.3	<0.001
Pleasantness					
Regular-energy 5g/sip	-0.9 (1.2)	-0.7 (1.3)	-0.7 (1.3)	0.4	0.68
Regular-energy 20g/sip	-1.3 (1.3)[b]	-0.8 (1.6)[a,b]	-0.7 (1.1)[a]	3.6	0.03
No-energy 5g/sip	-1.3 (1.2)[b]	-0.7 (1.2)[a]	-0.5 (1.4)[a]	5.8	0.004
No-energy 20g/sip	-1.0 (1.5)[b]	-0.4 (1.2)[a]	-0.4 (1.6)[a]	5.5	0.05

[a,b,c] Numbers within a row having lower case letters in common do not differ significantly [p<0.05].

‡ F-value from the ANOVA comparing the decline in subjective changes ratings of wanting and liking after orangeade consumption for each stimulus. All tests have 2,104 degrees of freedom, except for the tests in the regular-energy 20g/sip condition, which have 2,98 degrees of freedom.

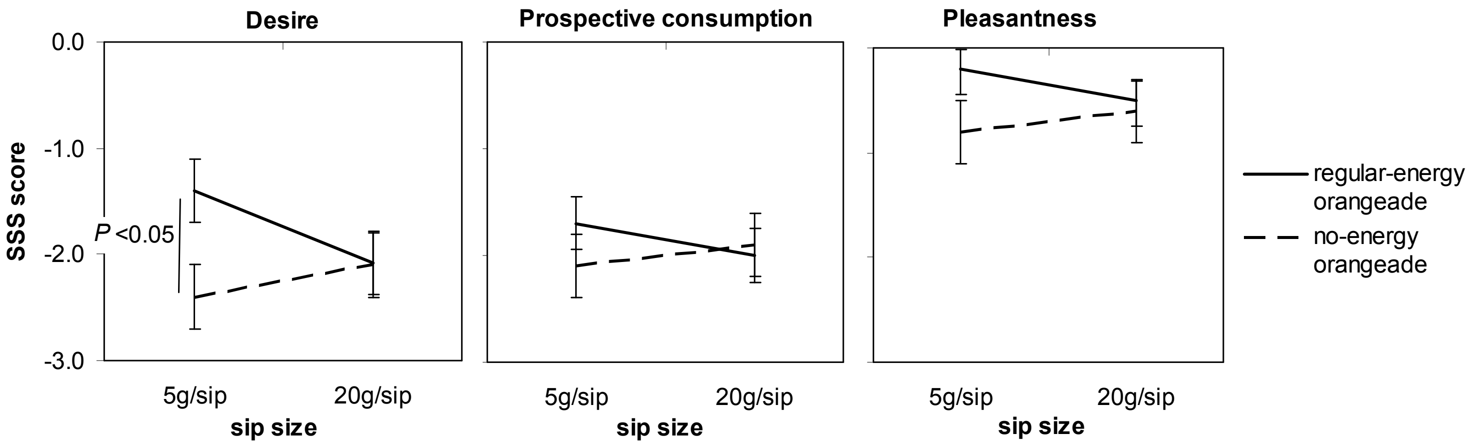

Figure 6.3: SSS scores* for each of the three SSS measures in each sip size condition (left: regular-energy orangeade; right: no-energy orangeade)
* SSS scores were calculated as follows: decline in the rating of the consumed orangeade – average decline in the rating of the non-consumed samples (tomato juice and milk).

Initial ratings of appetite and changes in appetite after orangeade consumption

All initial ratings of appetite were comparable across the four experimental conditions. The decline in each of the ratings of appetite was comparable between the two sip size conditions for the no-energy orangeade. The same applied for the regular-energy orangeade, except for the ratings of hunger [t(49)=2.3, *p*=0.03] and desired amount to consume [t(49)=2.5, *p*=0.02], which declined more in the large sip condition than in the small sip condition.

The decline in each of the ratings of appetite was comparable between the two orangeade types in the small sip condition. The same applied in the large sip condition, except for the decline in the desired amount to consume, which declined more for the regular-energy than for the no-energy orangeade [t(49)=2.6, *p*=0.01] (Table 6.3).

Table 6.3: Changes in appetite ratings from before to after *ad libitum* orangeade consumption in the four experimental conditions.

	Regular-energy, 5g/sip	Regular-energy, 20g/sip	No-energy, 5g/sip	No-energy, 20g/sip
Δhunger	-1.2 (1.4)*	-1.6 (1.5)	-1.6 (1.6)	-1.4 (1.3)
Δthirst	-3.4 (1.7)	-3.2 (1.7)	-3.2 (1.8)	-3.4 (2.1)
Δfullness	2.2 (1.7)	2.1 (1.8)	1.8 (1.8)	1.5 (1.9)
Δdesire to eat	-1.4 (1.7)	-1.4 (1.4)	-1.5 (1.6)	-1.2 (1.6)
Δdesired amount to consume	-1.2 (1.3)*	-1.6 (1.4)	-1.3 (1.5)	-1.0 (1.8)‡

* Change in appetite rating significantly different [p<0.05] from the change in the 20g/sip condition of the same orangeade.

‡ Change in appetite rating significantly different [p<0.05] from the change of the regular-energy orangeade in the same sip size condition.

Changes in ratings of sweetness after orangeade consumption

The ratings of perceived sweetness of the orangeades did not change after consumption of the orangeades, except for the perceived sweetness of the no-energy orangeade in the 20g/sip condition, which increased after consumption (mean increase=0.8±1.5, t(52)=3.7, p=0.001).

DISCUSSION

In line with our expectations, we found that subjects consumed less of the orangeades when consumed with small sips, i.e. with a prolonged oral sensory exposure. Despite the lower intake with small sips, subjective SSS scores were comparable between the two sip size conditions. This suggests that the development of sensory specific satiety for the orangeades was accelerated when consumed with small sips, and confirms that the length of oral sensory stimulation plays a role in the operation of satiety signals that drive the termination of food consumption.

The present results are line with the results from other studies. Lavin *et al.* showed that energy intake was lower after chewing sucrose-containing pastilles over 10 min, compared to after drinking a sucrose-containing beverage over 2 min (Lavin, French, Ruxton, & Read, 2002). Hetherington & Boyland (2007) showed that chewing sweetened gum decreased the desire for something sweet and intake of a sweet snack. The same phenomenon may explain the low satiating power of liquid calories as compared to calories from solid foods (Haber, Heaton, Murphy, & Burroughs 1977; Hulshof, De Graaf, Weststrate, 1993), and the weak compensatory response after consumption of liquid calories (Mattes, 1996; DiMeglio & Mattes, 2000; Mattes, 2006).

Previous studies proposed that a difference in oral work (i.e. chewing) is responsible for the differences in satiety between foods with different physiological properties (Oka, Sakuarae, Fuijse, Yoshimatsu, Sakata, & Nakata, 2003). The present results suggest, however, that a longer oral exposure to a stimulus, without necessarily affecting the oral work, promotes the development of sensory specific satiety. Probably, this is due to an intense perception of the sensory characteristics of the stimulus. Then, this supports the idea that the perceived intensity of a stimulus promotes the degree of sensory specific satiety for the stimulus (Vickers & Holton, 1998; Maier, Vickers, & Inman, 2006).

Evidence that viscous drinkable foods provide higher satiety ratings than more liquid foods, and that soups, consumed with a spoon, elicit stronger feelings of satiety than beverages seems to be congruent with the present findings (shakes differing in viscosity: Mattes & Rothacker, 2001; yoghurt vs. fruit drink: Tsuchiya, Almiron-Roig, Lluch, Guyonnet, Drewnowski, 2006; chocolate milk drink vs. cola: Harper, James, Flint, & Astrup, 2007; soup vs. juice: Mattes, 2005). The previous results could, however, also be explained by differences in the cognitive impression/expectations about the energy content the different stimuli impart to consumers (Tournier & Louis-Sylvestre, 1991; De Castro, 1993). A clear strength of the present study was that the stimuli imparted a similar cognitive impression about the energy content to consumers.

In the large sip condition, intake of the regular-energy orangeade was higher than intake of the no-energy orangeade, while SSS scores were comparable between the two types of orangeade. In the small sip condition on the other hand, SSS scores tended to be lower for the regular-energy than for the no-energy orangeade, while intake was comparable between the two orangeade types. These results both point to the same direction, i.e. they suggest that the development of sensory specific satiety is attenuated for regular-energy orangeade compared to no-energy orangeade. As the initial ratings of wanting and liking and the ratings of sweetness were equal between the orangeades, this finding cannot be explained by a difference in palatabililty (Beridot-Therond, Arts, Fantino, & De La Gueronniere, 1998) or in expectations about the energy content (Mattes, 1990). This result is neither supported by previous studies that compared the *ad libitum* intake (Rolls *et al.*, 1988; Rolls, B.J. *et al.*, 1989; Raben, Vasilaras, Moller, & Astrup, 2002) or SSS scores (Rolls *et al.*, 1988) between foods sweetened with synthetic sweeteners vs. foods sweetened with sucrose. Therefore, we can only speculate about possible explanations for this finding.

One possible explanation for the higher subjective SSS scores and the lower intake of the no-energy than of the regular-energy orangeade is the perception of off-flavours during consumption of the no-energy orangeade. The intensity of off-flavours, especially bitter and metallic tastes, has been shown to be higher in solutions sweetened with synthetic sweeteners than in sucrose solutions (Sedivá, Panovská, & Pokorny, 2006).

An alternative explanation may be that the reward value derived from sweet stimuli, which involves the endogenous opiate peptide system (Drewnowski, Krahn, Demitrack, Nairn, & Gosnell, 1995), is perhaps sustained longer when paired with energy than when the sweet taste is not paired with energy. This would require receptors in the oral cavity that detect whether a taste is paired with energy or not. The finding that the higher subjective SSS scores for no-energy orangeade than for regular-energy orangeade applied for the no-energy soft drink consumers but not for the regular-energy soft drink consumers maybe suggests a conditioned adaptive response. No-energy soft drink consumers may have learned by experience to sense the difference between a sweet taste paired with energy and a sweet taste not paired with energy.

Food reward is represented functionally and structurally by two distinct components, i.e. an affective (liking) and a motivational (wanting) component (Berridge, 1996). In the present study, ratings of wanting of the orangeades tended to decline more after orangeade consumption than ratings of pleasantness, and therefore SSS scores were larger when measured by the ratings of wanting than when measured by the ratings of liking [$p<0.001$ in each of the experimental conditions]. Previous studies support that eating a food to satiety may primarily generate changes in 'wanting' the food as opposed to 'liking' the food (Blundell & Rogers, 1991; Zandstra, De Graaf, Mela, & Van Staveren, 2000; Mela, 2001). Other studies found that ratings of wanting but not ratings of liking predicted intake (Zandstra, De Graaf, Mela, & Van Staveren, 2000; Zandstra, Weegels, Van Spronsen, & Klerk, 2004; Snoek, Huntjens, Van Gemert, De Graaf, & Weenen, 2004). Therefore future sensory specific satiety studies may focus on changes in wanting rather than in liking. However, as a subjective expression of one may inevitably contain elements of the other (Finlayson, King, & Blundell, 2007), it may be best to assess both components, except when using measures of wanting and liking that are less reliant on the cognitions of the subject.

In conclusion, the results suggest that the length of oral sensory stimulation to liquid foods may play a role in the development of satiety for the sensory characteristics of those foods. It may be that consumption of beverages with devices that prolong the oral sensory stimulation, such as straws or bottles with a small opening, may help to promote satiation, and thus to limit energy intake from the beverages. Moreover, in this experiment synthetically sweetened orangeade seems to generate more sensory specific satiety than orangeade sweetened with sucrose. This finding needs to be confirmed in other experiments.

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7

Discussion

This thesis focused on two issues that each influence the amount of energy consumed and therefore play a role in weight management. The first issue relates to making the right food choices. We investigated inter-personal differences that may explain why some people act on their stated healthy food choice intentions while others do not. The second issue relates to consuming sensible portions. We studied properties that affect the degree of sensory specific satiety for food, which is an important determinant of the termination of food intake.

This chapter starts with a brief overview of the main findings. Next, methodological considerations with respect to the selection of subjects and the designs of the studies are discussed. Furthermore, we discuss the new insights in the difficulty to make healthy food choices, and of food properties that affect sensory specific satiety and as such may play a role in the limitation of portion size. Finally, implications for health professionals and industry are given, and recommendations for further research are made.

MAIN FINDINGS

With respect to the intention-behaviour discrepancy, we demonstrated a substantial discrepancy between healthy snack choice intentions and actual snack choice; about 25% of the participants who intended to choose a healthy snack actually chose an unhealthy snack (Chapter 2 & 3). Males, lower educated individuals, individuals who are not habituated to choosing healthy snacks, and those who are not dietary restraint appeared to be especially susceptible for not translating their healthy snack choice intentions into action (Chapter 3).

With respect to sensory specific satiety, we showed that the taste intensity of snacks tended to be positively associated with the degree of sensory specific satiety they produce, while complexity tended to attenuate the promoting effect of intensity on sensory specific satiety (Chapter 4). The pleasantness over repeated exposure was sustained for soups and snacks with near to optimal arousal levels, while it declined for soups and snacks with lower arousal levels. Arousal level was defined as the combination of intensity and complexity (cf. Berlyne, 1970) (Chapter 4). The degree of sensory specific satiety for a stimulus did not predict its acceptance over repeated exposure (Chapter 4). Besides taste intensity and complexity, also snack size appeared to be associated with the degree of sensory specific satiety. *Ad libitum* snack intake was less for small, bite-size, snacks, than for bar-size snacks, which are consumed with larger bites (Chapter 5). Our data did not clearly support the idea that paying special attention to consumption reduces intake compared to usual consumption (Chapter 5). The association between bite size and the degree of sensory specific satiety extended to sip size; *ad libitum* intake was larger when orangeades were consumed with large sips compared to with small sips. This suggests that it is the length of oral sensory exposure rather than (or in addition to) the degree of oral work which affects the degree of sensory specific satiety (Chapter 6) (See Table 7.1).

Table 7.1: Overview of the main findings and conclusions.

Research question	Ch	Findings	Conclusions
Which proportion does not act on their healthy snack choice intentions?	2/3	Chapter 2: 27% of the participants who intended to choose a healthy snack actually choose an unhealthy snack. In Chapter 3 this proportion was 24%.	Healthy intentions are vital predictors of behaviour. Yet, a sizeable proportion of subjects does not enact their healthy snack choice intentions.
Which factors affect the susceptibility to a discrepancy between a healthy snack choice intention and actual choice?	2/3	Chapter 2: No significant associations. Chapter 3: Female gender [OR=1.9, 95%CI=1.1-3.5], high education [OR=3.4, 95%CI=1.7-6.8], dietary restraint [OR=1.3, 95%CI=1.0-1.6] and habitual healthy snack use [OR=1.4, 95%CI=1.1-1.9] strengthened the healthy intention-behaviour consistency.	Males, lower educated individuals, individuals who are not habituated to choosing healthy snacks, and those who are not dietary restraint are especially susceptible for not enacting their healthy snack choice intentions.
Do intensity and complexity of foods affect the degree of sensory specific satiety?	4	Trend for intense snacks to generate more sensory specific satiety (SSS) than less intense snacks, while complexity tended to attenuate the promoting effect of intensity on the generation of SSS [p=0.09]. No such associations for soups.	Intensity may promote sensory specific satiety, while complexity may attenuate this promoting effect.
Do intensity and complexity of foods affect the long-term acceptance of the foods?	4	Lower decline of pleasantness of the soup and snack with the near to optimal arousal level (= perceived complexity + perceived intensity) compared to the soup and snacks with lower arousal levels [soups: p=0.04; snacks: p=0.003].	The arousal level is important for food acceptance. Long term acceptance is sustained for optimally arousing stimuli, but declines for less arousing stimuli.
Can sensory specific satiety for a food predict long-term acceptance of the food?	4	No correlation between declines in pleasantness of the stimuli after consumption in the SSS tests and declines after repeated exposure [soups: r = -0.05, p=0.73; snacks: r = 0.20, p=0.19].	SSS does not seem to predict long term acceptance. Possibly, SSS is an implicit reaction to the food, while long-term acceptance also includes cognitions.
Do the bite-size of snack foods and the attention to consumption affect the degree of sensory specific satiety for the foods?	5	Lower intake for bite-size snacks than for bar-size snacks in the usual consumption condition [p=0.02]. No significant difference in subjective SSS scores between bars and nibbles [$p \geq 0.06$, ns]. No clear difference in intake or SSS scores of snacks between the attention and the control condition.	Eating with smaller bites results in a lower intake, probably due to a longer oral sensory stimulation. No support of the idea that attention to consumption increases SSS.
Do the sip-size and the energy content of orangeades affect the degree of sensory specific satiety for the orangeades?	6	Lower intake of orangeades when consumed with small compared to large sips [$p<0.001$ for both orangeades]. No difference in subjective SSS scores between sip sizes. Higher subjective SSS scores [p=0.01] for no-energy than for regular-energy orangeade, but no difference in intake (g) in small sip condition. Lower intake of no-energy than of regular–energy orangeade [p=0.02], but no difference in subjective SSS scores in large sip condition.	Drinking with smaller sips results in a lower intake. The longer oral sensory stimulation with small sips probably promotes sensory specific satiety. Sweet orangeade that provides energy may produce less sensory specific satiety than sweet orangeade without energy. Future studies need to confirm this finding.

METHODOLOGICAL CONSIDERATIONS

Study populations

Type of subjects

The participants of the studies described in chapter 2 and 3 of this thesis were all employees of large companies in the Netherlands. Permission to perform the study was obtained from the boards of the companies and the caterers that provided the lunches at the companies. Therefore, companies that paid special attention to the health of their employees and their customers might have been over-represented. This could have led to selection bias (Rothman & Greenland, 1998), i.e. to the selection of particularly health conscious subjects. As such, the discrepancy between healthy snack choice intentions and actual behaviour may have been underestimated. Indeed, the discrepancies found in our studies, which were around 25%, tended to be lower than those demonstrated in previous studies. For example, a review of health behaviours indicated that 47% of participants with positive intentions subsequently failed to perform their intended behaviour (Sheeran, 2002).

The recruitment through the companies may also have caused the homogeneity of the study populations. In both studies more than 80% of the participants were highly educated, the age range was 18-65 years, and the distributions of most personality factors measured by the questionnaires were smaller than would be expected from a random sample of the population (e.g. SD of health attitude in representative Finnish sample vs. our study populations: 1.3 (Roininen, Lähteenmäki, & Tuorila, 1999) vs. 1.0 (Chapter 2) and 0.9 (chapter 3); SD of taste attitude in representative Finnish sample vs. our study population: 1.0 (Roininen *et al.*, 1999) vs. 0.8 (Chapter 3); SD of dietary restraint in the Dutch population vs. our study populations: males=0.8 and females=0.9 (Van Strien, 2002) vs. males=0.8 and females=0.8 (Chapter 2), and males=0.7, females=0.7 (Chapter 3)) This might at least partly explain why none of the factors measured significantly distinguished between those who did and those who did not enact their healthy intention in the study described in chapter 2, and why in the study described in chapter 3 the factors that distinguished between those two groups of participants collectively explained only 6% of the variance in actual healthy snack choice. The effect size of these factors may have been larger in a more heterogeneous population.

Subjects for the sensory specific satiety studies described in chapter 4, 5, and 6 were recruited from advertisements in local newspapers and from flyers and posters which were distributed in university buildings. This recruitment procedure may also have been a source of selection bias; it may have attracted individuals who are highly motivated to participate in a scientific study. However, as the subjects were unaware of the aim of the studies, they could not know how to act 'correctly' or according to our expectations. Therefore, it is unlikely that this affected our study outcomes.

The recruitment for the studies described in chapter 4, 5, and 6 mainly attracted college-aged females. Dietary restraint people were excluded from participation in the studies. There are indications that the sensitivity to sensory specific satiety may differ between sexes (Smeets, De Graaf, Stafleu, Van Osch, Nievelstein, & Van der Grond, 2006), and between age groups (Rolls & McDermott, 1991). It has also been suggested that the sensitivity to sensory specific satiety may differ between dietary restraint and non-restraint people (Brunstrom & Mitchell, 2006). Therefore it should be investigated whether the results of these studies can be extrapolated to other populations, e.g. males, elderly, and dietary restraint people.

Inclusion of subjects with complete data only

In the studies described in chapter 2 and 3 the data of participants who did not return the questionnaire could not be used to predict the likelihood of making a healthy choice in terms of personality. Therefore, only the data of participants who had completed both choice tasks and returned the questionnaire were included for data-analysis. As the questionnaire addressed health issues, participants who had chosen an unhealthy snack might not have returned the questionnaire because they may have thought that they had acted 'incorrect'. The inclusion procedure may have therefore contributed to the underestimation of the discrepancy between healthy intentions and actual snack choices.

The study described in chapter 3 provided evidence for that. In the drop-outs after two choice tasks the proportion of actual healthy choices was lower than in the participants who completed the study (44% vs. 59%), while the proportion who did not act on their healthy intended choice was higher (30% vs. 24%). It thus remains to be investigated whether the proportion that did not act on their healthy snack choice intention can be extrapolated to other populations.

Number of subjects

A major strength of the studies described in chapter 2 and 3 was that the response rate was very high (around 80%) in both studies, and that the number of subjects was therefore very large (chapter 2: *N=585*, chapter 3: *N=538*), even though in both studies about half of the original participants (chapter 2: *N=1064*, chapter 3: *N=1017*) dropped out after the intended choice (in most cases this was probably due to the fact that they were occupied at the time of the actual choice). Therefore, we are confident that the participants were a representative selection from the population they were drawn from.

Before conducting the sensory specific satiety studies described in chapter 4, 5 and 6, we calculated the minimum number of subjects needed to detect a difference in sensory specific satiety scores between the experimental conditions of 10%, which we considered a relevant effect. In all these studies we were able to recruit a number of subjects that was sufficient to detect this difference with a power of 80%. Higher numbers of subjects would neither have changed our results nor our conclusions.

Study designs

Longitudinal rather than cross-sectional design

The design of the studies in chapter 2 and 3 was longitudinal rather than cross-sectional, i.e. intended choices were investigated prior to actual choices. This precludes the possibility that reported intentions follow from behaviour rather than the other way around. In the study described in chapter 2 the time between the intended and actual snack choice was one week, which may be larger than it would be in real life for a low involvement choice such as snack choice. Therefore, other influences than the perceived difficulty to enact the intended choice may account for the inconsistencies between the intended and actual choice. For example, participants may have forgotten their intended snack choice, or the taste of the participants may have changed (Loewenstein & Prelec, 1992). However, the fact that in the study described in chapter 3 the healthy intention-behaviour discrepancy was similar to the previous study (chapter 2), despite that the time between the intended and actual choice was only one day, supports that it was in both studies mainly the perceived difficulty to enact the intended choice that affected the healthy intention-behaviour discrepancy.

Observation of choices rather than relying on self-reports

The findings presented in chapter 2 and 3 of this thesis are based on observational data. We actually observed food choices, rather than that they were reported by the participants, as was done in most previous studies that investigated healthy eating behaviour (Brug, De Vet, De Nooijer, & Verplanken, 2006; Jackson, Lawton, Knapp, Raynor, Conner, Lowe, *et al*., 2005; Verbeke & Pieniak, 2006; Sparks, Conner, James, Shepherd, & Povey, 2001). A clear advantage of actually observing food choices is that the responses are not affected by possible self-representational biases (Gaes, Kalle, & Tedeschi, 1978). However, a disadvantage of this method is that the choices may be affected by desirability characteristics, i.e. when facing the experimenter participants might have felt forced to actually choose the same snack as they had indicated (i.e. intended) to choose. This might have decreased the discrepancy between healthy intentions and actual behaviour. The discrepancy of around 25%, as found in the study described in chapter 2, was however comparable to the discrepancy found in the study described in chapter 3. The design of the latter study was adapted to prevent this type of desirability characteristics, i.e. participants were offered different sets of healthy and unhealthy snacks at intended and actual choice.

Single measurement of intended and actual choices

In the studies described in chapter 2 and 3 intended and actual snack choice were both only assessed once. As food choice is a highly repeatable behaviour, and as single healthy or unhealthy choices hardly affect the energy balance, it may not be relevant for public health outcomes to measure single healthy choices. Moreover, a single intention measurement precludes taking intention stability into account, which has previously been suggested as an important factor in the consistency between intentions and behaviour (Sheeran, Orbell, Trafimow, 1999). However, single choices might at least give an indication of the choices people on average make, especially when measured in a large population. Whether the size of the discrepancy between healthy snack choice intentions and actual choices found in the present studies can be extrapolated to repeated snack choices needs to be investigated. Ideally, future studies that investigate the issue of intention–behaviour discrepancies in food choice should observe food choices for a follow-up time of a set number of days or weeks. However, then the subjects' awareness that their food choices are being observed will most likely affect the outcomes.

Categorization of snack choices by investigators

In the studies described in chapter 2 and 3, the snacks were categorized by the investigators as either healthy or unhealthy, based on data of a pilot study in which the perceived healthiness of several snacks was inquired. The participants were thus assumed to categorize the snacks on the healthy-unhealthy dimension. Although evidence suggests that even children automatically discriminate between healthy and unhealthy foods (Young, 2000), it may have been that some participants did not categorize the snacks on the health dimension, but used another logic to be consistent, e.g. the logic of choosing a biscuit based snack both at intended choice and at actual choice. This may have especially influenced the results of the study described in chapter 3, as both 'healthy' and 'unhealthy' biscuit based snacks were offered. However, an analysis of the results categorizing the snacks on the basis of their physical and sensory similarity instead of on the basis of healthiness revealed that the characteristics of subjects who intended to choose a 'healthy' biscuit but chose an 'unhealthy' biscuit were similar to those who changed from another healthy snack to an unhealthy snack, while the characteristics of the subjects who intended to choose a 'healthy' biscuit and subsequently chose another 'healthy' biscuit were similar to those who intended to choose another healthy snack and indeed chose a healthy snack. This confirms that the subjects generally categorized the snacks on the healthy-unhealthy dimension.

Measurement of sensory specific satiety (SSS): fixed or ad libitum amount?

In the sensory specific satiety study described in chapter 4, SSS of snacks was measured after consumption of a fixed amount of the snacks, which was the average amount that women could eat in a pilot study without developing aversion. This procedure has been widely used to measure SSS (e.g. Johnson & Vickers, 1992; Chung & Vickers, 2007; Bell, Roe, & Rolls, 2003). A disadvantage of this procedure is however, that after consumption of the fixed amount, some subjects may have developed complete sensory satiety for all snacks or no satiety at all for any of the snacks, which makes it impossible to uncover differences the degree of sensory specific satiety between the snacks. This may have led to smaller differences in SSS scores between the snacks than would have been measured if we had allowed the subjects to consume an *ad libitum* amount of the snacks. This might at least partly account for the fact that our findings of the snack study in chapter 4 were not significant.

We chose for measuring sensory specific satiety after consumption of an *ad libitum* amount of the test foods in the soup study described in chapter 4, and in the studies described in chapter 5 and 6. This procedure has also been previously used (e.g. Guinard & Brun, 1998; Hetherington, Rolls, & Burley, 1989) and enabled us to use *ad libitum* intake of the stimuli as an implicit measure of sensory specific satiety (Vickers & Holton, 1998; Miller, Bell, Pelkman, Peters, & Rolls, 2000; Rolls & McDermott, 1991). The disadvantage of this method is that differences in intake may confound the subjective SSS measures (Vickers, Holton, & Wang, 1998).

Despite the disadvantage of *ad libitum* intake for the use of subjective sensory specific satiety scores, we advocate choosing for *ad libitum* intake of the test foods rather than a for fixed intake, as it ensures that all subjects can eat until satiated with the food, and it allows to compare intake between the test foods as an implicit measure of sensory specific satiety. Measures of intake may be more sensitive to detect differences in sensory specific satiety between foods than subjective measures of SSS, as subjective measures depend on the subject’s usage of the rating scales.

Measurement of intake as an implicit measure of sensory specific satiety

Comparing intake between foods as a measure of a difference in SSS between foods is only feasible within certain conditions. First, as there is evidence that food intake is influenced by expectations about the energy content of the food (Mattes, 2006), the stimuli that are compared should impart similar expectations about the energy content. Secondly, it only makes sense to compare intake of foods within a given category, as, obviously, the volume of foods usually consumed largely differs between food categories (e.g. comparing intake between bread and chocolate as a measure of a difference in SSS between these foods is not sensible). Thirdly, intake measures cannot be used as measures of SSS when aiming to compare SSS between meals that consist of more than one component. The foods used in our studies that compared intake measures between foods as measures of SSS satisfied the three conditions mentioned above.

The studies in the present thesis, in which intake between foods was compared as a measure of a difference in SSS, consistently showed that, while intake differed between foods, subjective SSS scores were comparable between foods. This suggests that people consume a food until a given decline in wanting / reward derived from consumption has occurred. In other words, the decline in reward required for the termination of consumption may always be constant, while the amount of food required to reach that decline may differ between foods. As far as we are aware of, studies that aimed to test this suggestion do not exist. Future studies should therefore confirm this suggestion, and should investigate whether the decline in reward required to terminate consumption is similar among people and among foods of different categories.

Measurement of sensory specific satiety: decline in wanting or in liking?

Although originally considered as interchangeable, growing evidence supports that liking and wanting are separate neural processes, and therefore represent two distinguishable phenomena even though they are highly correlated (Berridge, 1996). Mela (2001) has suggested that eating food until satiated may primarily influence the ratings of ‘wanting’ the food as opposed to ‘liking’ the food. To measure sensory specific satiety in our study the decline in ratings of pleasantness (i.e. liking), as well as the decline in ratings of desire to eat the food (i.e. wanting) was assessed, as was done in previous studies (e.g. Guinard & Brun, 1998; Miller, Bell, Pelkman, Peters, & Rolls, 2000; Hetherington & Boyland, 2007). Although sensory specific satiety was demonstrated by the decline in ratings of pleasantness as well as by the decline in ratings of desire, in general, sensory specific satiety scores were larger when assessed by the decline in ratings of desire. This supports the suggestion that eating food until satiated may primarily influence the ratings of wanting the food as opposed to liking the food. The decline in ratings of desire may thus better reflect sensory specific satiety than the decline in ratings of pleasantness.

THE DIFFICULTY TO ACT ON HEALTHY FOOD CHOICE INTENTIONS, NEW INSIGHTS

As noted in the introduction of this thesis, little was known about the proportion of people who do not act on their healthy food choice intentions, and, although it was generally recognized that some people are better able than others to enact their healthy food choice intentions, the factors that are associated with these differences were largely unknown.

One out of four participants chose an unhealthy snack, despite a healthy intention

In the study described in chapter 2 we found that 27% of the participants who stated a healthy snack choice intention did not translate this intention into action, but chose an unhealthy snack instead. In the study described in chapter 3, this proportion was about the same, i.e. 24%. Above we mentioned reasons to assume that this proportion may be different in other groups of subjects, and when intentions and behaviour are repeatedly measured. However, it is a substantial proportion, which indicates that effective strategies to facilitate people to make healthy food choices are required. Despite that, participants who intended to choose a healthy snack far more often actually chose a healthy snack than participants who intended to choose an unhealthy snack. This suggests that if people plan to eat healthily they are at least more likely to do so than when they do not make such plans.

Dietary restraint and habitual consumption of healthy foods facilitate the enactment of one's healthy food choice intentions

Participants who were highly dietary restraint and those who were habituated to eating healthy snacks were more likely to enact their stated healthy snack choice intention than those who were not dietary restraint and those who were not habituated to eating healthy snacks, after controlling for other factors (Chapter 3). This seems to confirm the suggestion that dietary restraint people have a high patience for health benefits, and therefore their explicit positive attitudes towards healthy foods are likely to outweigh possibly diverging implicit attitudes when the choice is implemented. People who are habituated to eating healthy snacks may have congruent explicit and implicit attitudes towards healthy foods, i.e. they consider them as both healthy and enjoyable, and may therefore perceive little difficulty to enact their healthy food choice intentions.

Males and lower educated people susceptible for not acting on their healthy food choice intentions

Male participants and those who were lower educated were more likely not to enact their stated healthy snack choice intention than females and higher educated participants. These associations were probably at least partly mediated by other factors such as health attitude and habit. However, even if the underlying causal processes are not well understood it is useful to be able to predict the performance or nonperformance of an intended behaviour in terms of demographic characteristics. This enables interventions that aim at facilitating healthy choices to target at particularly susceptible subgroups.

PROPERTIES THAT MAY FACILITATE CONSUMING SENSIBLE PORTIONS, NEW INSIGHTS

Before the start of our studies, the phenomenon of sensory specific satiety had been widely studied. It had for example been demonstrated that sensory specific satiety does not depend on the ingestion of calories, as it was generated when only smelling the food (Rolls & Rolls, 1997), or when sham-feeding rather than swallowing (Smeets & Westerterp-Plantenga, 2006). It had also been shown that sensory specific satiety for a food clearly extends to foods with similar sensory characteristics, i.e. similar flavours and/or textures, but to a lesser extend to foods with similar macronutrients (see review by Sørensen, Møller, Flint, Martens, Raben, 2003). Despite that, before the start of our studies, studies of properties that drive the development of sensory specific satiety were only scarce. This is surprising, as consumption of a diet that consists of foods that produce a high degree of sensory specific satiety could help to control food intake, and therefore to facilitate weight management.

Sensory specific satiety tends to develop quickly for intense foods

Data of the snack study reported in chapter 4 support that intensely tasting foods rapidly produce sensory specific satiety (cf. Vickers & Holton, 1998; Maier, Vickers, & Inman, 2007). This confirms the suggestion that the more intense a sensory characteristic is perceived, the more rapid the optimal level of stimulation for that characteristic declines below the perceived level. However, the association was only borderline significant. Therefore, more studies are needed to confirm this association.

Complexity tends to attenuate the sensory specific satiety promoting effect of intensity

The data also support the idea that complexity reduces sensory specific satiety (cf. Johnson & Vickers, 1992); snacks with a comparably intense taste produced less sensory specific satiety if they consisted of more different sensory characteristics, i.e.

if they were more complex (Chapter 4). This confirms the suggestion that the variety of sensory characteristics provides that the optimal level of stimulation by a food is sustained close to the perceived level for a long time. However, as also this association was only borderline significant, this finding needs to be confirmed as well. Ideally, the stimuli used in future studies should only differ in the sensory characteristic of interest, e.g. in flavour intensity or in complexity, while all other sensory characteristics, and also the hedonic evaluation, are equal between the stimuli.

Optimal arousal provides a basis for sustained acceptance of foods over repeated exposure

From the snack study in chapter 4 it appeared that the acceptance of snacks that provide an arousal level, i.e. a combination of complexity and intensity (cf. Berlyne, 1970), that is close to the individual optimum was sustained after a daily exposure over 5 days, while the acceptance of snacks that provided a lower than optimal arousal level declined over repeated exposure. For most individuals, the snack that was closest to the individual's optimum arousal level (i.e. was the most preferred snack) provided the highest arousal level. Therefore, the idea that repeated exposure to stimuli that are slightly more complex than the individual's optimum level would cause an upward shift of the optimum, and a decline in liking of stimuli with the previous optimum complexity level (Levy, MacRae, & Köster, 2006), could not be tested.

Food intake is limited when food is consumed with small bites or sips

When snacks were consumed with small bites (Chapter 5), and when orangeades were consumed with small sips (Chapter 6), less was consumed than when they were consumed with larger bites or sips. These data suggest that consumption with small bites or sips promotes sensory specific satiety. Consumption with small bites extends the oral sensory stimulation due to an increase in the oral work per consumption (Spiegel, 2000), while consumption with small sips only affects the oral sensory stimulation but not the oral work (German, Crompton, Owerkowicz, & Thexton, 2004). This suggests that it is not just the activation of neuronal histamine in the hypothalamus by chewing (Sakata, Yoshimatsu, & Kurokawa, 1997) that is responsible for this sensory specific satiety promoting effect. Probably, a long oral sensory stimulation increases the intensity by which the sensory characteristics of foods are perceived, and therefore the degree of sensory specific satiety for the foods.

Sensory specific satiety does not predict long-term acceptance

The data did not support the idea that the degree of sensory specific satiety for a food predicts its long-term acceptance (Chapter 4). Probably, the basis of SSS is merely an implicit biological (neurological) reaction to the sensory quality of the food, whereas acceptance over repeated exposure involves cognitions about the overall eating situation rather than, or in addition to, a biological reaction. Moreover, repeated exposure to foods may bring about changes in optimal levels of the sensory characteristics of which the food consists (cf. Berlyne, 1970), which may not occur during the single exposure in a sensory specific satiety protocol.

IMPLICATIONS FOR PRACTICE

The knowledge that dietary restraint and habitual healthy snack use facilitate acting on healthy food choice intentions may have implications for the content of intervention programs that aim at facilitating people to enact their healthy food choice. These interventions should be directed at imposing self-control by enhancing the attractiveness of waiting for delayed benefits, and at making sure that healthy foods are widely available. The effectiveness of the interventions may increase by targeting males and lower educated people, as these groups are especially susceptible for not acting on their healthy food choice intentions. As our findings suggest that about half of the population does not even intend to make healthy food choices, interventions should also be directed at motivating this group to eat healthily.

A high degree of SSS for a food does not necessarily lead to the loss of its acceptance over repeated exposure. This opens the window for stimulating consumption of foods which produce a high degree of sensory specific satiety as a strategy for weight management. As foods with a highly intense taste promote sensory specific satiety, encouraging consumption of intense foods may be successful for the limitation of portion sizes. Portion size could also be limited by encouraging people to consume their meals with small bites and sips. These strategies may help people to be satisfied with less food.

RECOMMENDATIONS FOR FURTHER RESEARCH

Besides answering questions, the present thesis raised many suggestions for further research. Major recommendations that emerged from this thesis are listed below:

1. The data suggest that dietary restraint people are especially likely to enact their healthy food choice intentions. We propose that their high patience for health benefits underlies this. Evidence of this could be provided by first measuring individual patience of dietary restraint and non-restraint people, and secondly directly investigating the associations between the degree of patience of people and their food choice intentions and actual food choices. Patience could be measured using the delay discount procedure (Madden, Retry, Badger, & Bickel, 1997), in which participants indicate preference for immediate versus delayed money (e.g. 'what would you prefer, 100 euros right now or 110 euros in a week?') in a procedure that determines indifference points at various delays. A strong devaluation of delayed money indicates a low degree of patience.

2. The data suggest that people who habitually use healthy snacks are likely to enact their healthy food choice intentions. We put forward that their congruent explicit and implicit attitudes may underlie that. To provide a conclusive test of this hypothesis, besides explicit attitudes also implicit attitudes of subjects towards healthy foods should be measured, next to observing their intended and actual food choices. Implicit attitudes could be measured by the Implicit Association Test (Greenwald, McGhee, & Schwartz, 1998), which measures differential association of 2 target concepts (e.g carrot vs. chocolate bar) with an attribute (e.g. pleasant words). When

highly associated categories (e.g., chocolate bar + pleasant) share a response key, performance is faster than when less associated categories (e.g. carrot + pleasant) share a key. The difference in performance speed implicitly measures differential association of the 2 concepts with the attribute.

3. As mentioned above, it appeared that non-dietary restraint people are particularly susceptible for not enacting their healthy snack choice intentions. A plausible explanation is that impulsive people (e.g. low in dietary restraint) make their food choices on the basis of implicit attitudes (Guerrieri, Nederkoorn, & Jansen, 2007). It could be, that impulsive people also rely more on implicit cues, such as sensory specific satiety, to regulate the amount consumed, while less impulsive persons may rely more on cognitive control. An approach as used by Hetherington (1996), i.e. asking people for their main reasons to stop consumption, could be used to study that. Although research has shown that highly dietary restraint people are more impulsive than controls (Nederkoorn, Van Eijs, & Jansen, 2004), these two concepts reflect slightly different phenomena: Impulsivity is a trait, while dietary restraint is a response to the perceived need to control weight (Hetherington, 2007). Therefore, rather than by a measure of dietary restraint (such as the restraint scale of the DEBQ, Van Strien, 2002), impulsivity could be measured by a self-report measure, e.g. the Barratt Impulsiveness Scale (Patton, Stanford, & Barratt, 1995), or a behavioural measure, e.g. the stop-signal task (Logan, Schachar, & Tanock, 1997. In the stop-signal task subjects perform a choice reaction time (go) task and are asked to inhibit their responses to the go task when they hear a stop signal. Stop-signal reaction time can be estimated by subtracting stop signal delay from go signal reaction time, and is longer in more impulsive subjects.

4. Consumption with small bites and sips results in a lower food intake. Although we suggest that this is due to the long oral sensory stimulation, which promotes the development of sensory specific satiety, the study designs did not preclude the possibility that this is due to other reasons, e.g. due to boredom with the task. This could be investigated by using a modified experimental design, in which subjects are surprised after the SSS protocol with a second course of a food with the same sensory characteristics, without constraints on bite- or sip-size.

5. A conclusive test of our suggestion that consumption of foods reduces the individual optimum level of sensory characteristics of the food is needed. The

following design could be used. Subjects consume a food with a single dominant (intense) sensory characteristic to satiety, and rate the pleasantness of the food before and after consumption. Before and after consumption they also rate the pleasantness of a similar food, in which the intensity of the sensory characteristic is much lower, and of other foods which contain the dominant sensory characteristic at a same level of intensity as the consumed food, and at a lower level.

6. Although the results suggest that consumption of small, bite-size, snacks results in a lower intake than consumption of bar-size snacks, this should be investigated in a natural setting, in which attendance to sensory cues is often limited, and cognitive control may be important to limit intake. It may be easier to cognitively monitor consumption of bar-size snacks than bite-size snacks, and therefore easier to limit intake of the bar-size snacks in a natural setting.

7. Our findings seem to support the idea that eating food to satiety may affect the desire to eat the food but not the pleasantness of the food (Mela, 2001). This represents a potentially interesting area for future research. Despite the fact that separate brain substrates have been identified for each of these processes (Berridge, 1996), their independent operation is difficult to establish using the kind of subjective measures of desire and pleasantness that were employed in our studies. Instead of subjective measures, biological measures by means of fMRI brain scans could be used. Another potentially promising procedure that seems to dissociate 'liking' from 'wanting' has recently been developed by Finlayson and colleagues (Finlayson, King, & Blundell, 2007). In this procedure liking is assessed trough pleasantness ratings ('how pleasant would it be to experience a mouthful of this food now'), while wanting is assessed through a forced-choice procedure in which subjects are presented with pairs of foods and are forced to select the foods they 'would most *like* to eat now'.

8. Levy *et al.* (2007) suggested that the relative perceived complexity of a stimulus may diminish after repeated exposure. In case complexity attenuates sensory specific satiety (SSS), the degree of SSS that develops after consumption of a stimulus of a given complexity should be higher after repeated consumption of the food than when the food is novel. Or in general, long-term exposure to foods may affect the degree of sensory specific satiety for the foods. In support of this suggestion, a recent study (Weenen, Stafleu, & De Graaf, 2005) found that more SSS developed for cheese

biscuits after than before daily exposure to the biscuits for 6 days. Future studies are needed to confirm this and to study the implications for food intake.

9. The data suggest that the decline in reward required to terminate consumption is always constant for a person, while the amount consumed that is necessary to reach that decline may differ between foods. This may have implications for the use of SSS scores for a food as measures to predict food intake. Therefore, biological measurements by means of fMRI brain scans are needed to confirm that hypothesis. If the hypothesis turns out to be true, it should be investigated whether the decline differs among persons and among foods of different categories.

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Summary

Globally, the problem of obesity reaches epidemic proportions. Obesity is caused by a long-term positive energy balance, i.e. a higher energy intake than energy expenditure. The present thesis focused on two issues that affect energy intake, i.e. food choice and food intake. More specific, we investigated differences between persons in their ability to act on their healthy food choice intentions. Understanding these differences can help health professionals to design effective strategies that facilitate making healthy food choices. Secondly, we investigated food properties that affect the development of sensory specific satiety, which is an important implicit cue to regulate the amount consumed. Consumption of foods with properties that promote sensory specific satiety may help people to consume sensible portions.

DISCREPANCY BETWEEN INTENTIONS AND ACTUAL CHOICES

Chapter 2 and 3 were dedicated to the difference between snack choice intentions and actual snack choices. We investigated which proportion of the participants would not act on their healthy snack choice intentions. Moreover, we investigated which persons would be more susceptible than others for not translating their healthy snack choice intentions into action. Participants, office employees (Chapter 2: *N=585*; Chapter 3: *N=538*), indicated their intended snack choice from a set of snacks, either perceived as healthy or unhealthy (not labeled as such). Some time later (Chapter 2: one week; Chapter 3: one day), they actually chose a snack, either from the same set of snacks as at intended choice (Chapter 2), or from a set of different alternatives (Chapter 3). Within one week after the actual choice, they completed a questionnaire that evaluated several demographic and personality constructs.

The results showed that in both studies about 25% (Chapter 2: 27%; Chapter 3: 24%) of the participants chose for an unhealthy snack, despite a healthy intention. Despite that, healthy intentions were important predictors of actual healthy snack choice.

In chapter 2, no associations between demographic or personality factors and the translation of snack choice intentions into action were found. In chapter 3 we showed that, after controlling for other factors, males [OR=1.9, 95%CI=1.1-3.5], lower educated people [OR=3.4, 95%CI=1.7-6.8], non-dietary restraint people [OR=1.3, 95%CI=1.0-1.6], and people who are not habituated to choosing healthy snacks

[OR=1.4, 95%CI=1.1-1.9], are particularly susceptible for not acting on their healthy snack choice intentions.

PROPERTIES THAT AFFECT SENSORY SPECIFIC SATIETY

The studies reported in chapter 4, 5, and 6 focused on differences in the degree of sensory specific satiety between foods. In the two studies described in chapter 4 we investigated the associations between the development of sensory specific satiety for a stimulus, and its taste intensity and complexity, i.e. the variety of sensory characteristics the stimulus consist of. Moreover, in both studies the acceptance over repeated exposure of the stimuli (study 1: daily for 14 days; study 2: daily for 5 days) was examined. Finally, we investigated whether the acceptance of a stimulus after consumption to satiety can predict the long-term acceptance of the stimulus. The stimuli in study 1 (N=*66*) were soups; in study 2 (N=*61*) snacks were used. Sensory specific satiety (SSS) was calculated as the decline in ratings of wanting and liking of the test-stimulus after consumption of an *ad libitum* (soups) or fixed (snacks) amount, relative to the decline of non-consumed foods.

Although the results of the soup study did not support the idea that intensity or complexity of foods affect the development of sensory specific satiety, the results of the snack study showed that intensity tended to promote sensory specific satiety for snacks, while complexity tended to attenuate the promoting effect of intensity; comparably intense snacks produced less sensory specific satiety if they were more complex [p=0.09].

In both studies, the arousal level of the stimuli (i.e. the combination of complexity and intensity) affected their acceptance over repeated exposure. The acceptance of stimuli with the optimal (i.e. most preferred) arousal level was sustained over repeated exposure, while the acceptance declined for less arousing stimuli [soups: p=0.04; snacks: p=0.003].

None of the studies provided evidence for the idea that the acceptance of a stimulus after consumption to satiety can predict its acceptance over repeated exposure [soups: r = -0.05, p=0.73; snacks: r = 0.20, p=0.19]. Possibly, sensory specific satiety is an implicit reaction to the food consumed, while food acceptance over repeated exposure is also affected by cognitions about the overall eating situation.

Sensory specific satiety is not only influenced by intensity or complexity, but also by the bite-size with which foods are consumed. The study described in chapter 5 (*N=59*) showed that *ad libitum* snack intake was 12% lower for nibbles, bite-size snacks, than for bars, which are consumed with larger bites [p=0.02]. Despite the lower intake, SSS scores were comparable between the bars and the nibbles [$p \geq 0.06$], which suggests a more rapid development of SSS for the nibbles.

In this study we also investigated whether attention to consumption would accelerate the development of sensory specific satiety for the snacks. The data did not clearly support this idea; attention neither affected snack intake [$p \geq 0.13$], nor subjective SSS scores [$p \geq 0.08$].

A similar study described in chapter 6 (*N=53*) demonstrated that the association between sensory specific satiety and bite size extends to sip size. This suggests that a prolonged oral sensory stimulation accelerates sensory specific satiety, possibly due to an intense perception of the food's sensory characteristics. Mean intake of regular-energy orangeade was 29% lower, while mean intake of no-energy orangeade was 16% lower when consumed with small (5g) sips vs. when consumed with large (20g) sips [both $p<0.001$]. Despite the lower intake with small sips, SSS scores of both types of orangeade were comparable between the sip size conditions.

In addition, this study showed an association between the development of sensory specific satiety and energy content of the orangeades, which is not supported by data of previous studies. When consumed with large sips, mean intake of synthetically sweetened orangeade (no energy) was 18% [p=0.02] lower than of the orangeade sweetened with sucrose (energy containing). When consumed with small sips, mean intake was comparable between the two types of orangeade. Yet, subjective SSS scores of desire were higher for the no-energy orangeade than for the regular-energy orangeade [p=0.01]. Future studies are needed to confirm and explain this finding.

CONCLUSION

Males, lower educated people, non-dietary restraint people, and those who are not habituated to choosing healthy snacks are particularly susceptible to not enacting their healthy food choice intentions. Intervention programs that aim at facilitating people to enact their healthy food choices should target males and lower educated people, and focus on increasing their healthy snacking habit and self-control.

Consumption of high intensity foods and consumption of foods with small bites or sips promotes sensory specific satiety. The promotion of high intensity foods and encouraging people to consume their meals with small bites and sips could be successful strategies to facilitate people to limit their portion sizes.

Samenvatting

Ernstig overgewicht neemt wereldwijd epidemische vormen aan. Overgewicht wordt veroorzaakt door langdurig meer energie in te nemen dan te verbruiken. In dit proefschrift staan voedselkeuzes en -inname centraal, factoren die beide de totale energie-inname beïnvloeden. Specifiek hebben we verschillen tussen mensen onderzocht in het vermogen om intenties tot het maken van gezonde voedselkeuzes in gedrag om te zetten. Meer begrip hiervan kan bijdragen bij het ontwikkelen van effectieve strategieën om het maken van gezonde keuzes gemakkelijker te maken. Daarnaast hebben we eigenschappen van voedingsmiddelen onderzocht die de ontwikkeling van sensorisch specifieke verzadiging beïnvloeden. Sensorisch specifieke verzadiging speelt een belangrijke rol bij het stoppen met eten. Consumptie van voedingsmiddelen die sensorisch specifieke verzadiging bevorderen kan dus helpen om kleinere porties te eten.

HET VERSCHIL TUSSEN INTENTIES EN GEDRAG

In hoofdstuk 2 en 3 hebben we verschillen tussen intenties en daadwerkelijk gedrag in de keuze voor tussendoortjes onderzocht. We onderzochten welk deel van de deelnemers zich niet aan zijn/haar intentie tot het kiezen van een gezond tussendoortje zou houden. Ook onderzochten we verschillen in eigenschappen tussen personen die hun gezonde intentie wel dan wel niet omzetten in gedrag. Deelnemers, kantoormedewerkers van verschillende bedrijven (Hoofdstuk 2: *N=585*; Hoofdstuk 3: *N=538*), gaven op papier aan welke van verschillende tussendoortjes ze zouden willen kiezen (intentie-keuze). De tussendoortjes werden ofwel als gezond, ofwel als ongezond beschouwd, maar waren niet als zodanig gemerkt. Enkele tijd later (Hoofdstuk 2: eén week; Hoofdstuk 3: eén dag) kozen ze daadwerkelijk een tussendoortje. In hoofdstuk 2 kozen ze uit dezelfde tussendoortjes als bij de intentie-keuze; in hoofdstuk 3 werden andere gezonde en ongezonde tussendoortjes aangeboden. Binnen een week na de daadwerkelijke keuze vulden de deelnemers een vragenlijst in met betrekking tot demografische gegevens en verschillende eigenschappen.

Beide studies lieten zien dat ongeveer 25% van de deelnemers (Hoofdstuk 2: 27%; Hoofdstuk 3: 24%) met de intentie tot het kiezen van een gezond tussendoortje, in plaats daarvan een ongezond tussendoortje koos. Ondanks dat was een gezonde intentie een belangrijke voorspeller voor daadwerkelijk gezond gedrag. In hoofdstuk 2 vonden we geen verband tussen demografische gegevens of de andere gemeten eigenschappen en het wel dan wel niet omzetten van een gezonde intentie in gedrag. In hoofdstuk 3 vonden we echter dat mannen [OR=1.9, 95%CI=1.1-3.5], laag opgeleide mensen [OR=3.4, 95%CI=1.0-1.6], mensen die geen lijngericht eetgedrag vertonen [OR=1.3, 95%CI=1.1-1.9], en mensen die gewoonlijk geen gezonde tussendoortjes eten [OR=1.4, 95%CI=1.1-1.9] een verhoogde kans hebben om, ondanks een gezonde intentie, voor een ongezond tussendoortje te kiezen.

FACTOREN DIE SENSORISCH SPECIFIEKE VERZADIGING BEÏNVLOEDEN

De studies die beschreven zijn in hoofdstuk 4, 5, en 6 waren gericht op verschillen tussen voedingsmiddelen in de mate van sensorisch specifieke verzadiging (SSS) die zij teweeg brengen. In de twee studies beschreven in hoofdstuk 4 onderzochten we het verband tussen de mate van sensorisch specifieke verzadiging voor voedingsmiddelen, en hun intensiteit en complexiteit, d.w.z. de hoeveelheid verschillende sensorische eigenschappen waaruit ze bestaan. Bovendien hebben we in beide studies de acceptatie van de voedingsmiddelen op de langere termijn, na herhaalde blootstelling, onderzocht (studie 1: dagelijks gedurende 14 dagen; studie 2: dagelijks gedurende 5 dagen). Ten slotte onderzochten we in hoeverre de mate van sensorisch specifieke verzadiging voor een voedingsmiddel de acceptatie van het voedingsmiddel na herhaalde bloostelling voorspelt. De voedingsmiddelen in studie 1 (*N=66*) waren soepen; in studie 2 (*N=61*) hebben we tussendoortjes gebruikt. Sensorisch specifieke verzadiging (SSS) werd gemeten als de afname in de acceptatie van het voedingsmiddel, na consumptie van een *ad libitum* (voor de soepen) of een vaste (voor de tussendoortjes) hoeveelheid, ten opzichte van de afname van andere, niet gegeten, voedingsmiddelen.

De resultaten van de studie met de soepen ondersteunden een mogelijk verband tussen de intensiteit of de complexiteit van een voedingsmiddel en de mate van sensorisch specifieke verzadiging niet. Echter, de studie met de tussendoortjes liet zien dat intensiteit sensorisch specifieke verzadiging leek te bevorderen, terwijl complexiteit dit bevorderende effect leek af te remmen; tussendoortjes van vergelijkbare intensiteit brachten minder sensorische verzadiging teweeg als ze meer complex waren [p=0.09].

In beide studies werd de acceptatie van de voedingsmiddelen na herhaalde bloostelling beïnvloed door de totale stimulatie die het voedingsmiddel teweeg bracht, d.w.z. door de combinatie van complexiteit en intensiteit. De acceptatie van voedingsmiddelen die een optimale stimulatie teweeg brachten (d.w.z de mate van stimulatie die de hoogste voorkeur had) bleef behouden na herhaalde bloostelling, terwijl de acceptatie afnam voor voedingsmiddelen die minder stimulatie teweeg brachten [soepen: p=0.04; tussendoortjes: p=0.003].

In geen van de studies konden we aantonen dat de mate van sensorisch specifieke verzadiging voor een voedingsmiddel de acceptatie na herhaalde blootstelling voorspelt [soepen: r=-0.05, p=0.73; tussendoortjes: r=0.20, p=0.19]. Wellicht is sensorisch specifieke verzadiging voornamelijk een biologisch process, terwijl bij acceptatie na herhaalde blootstelling ook bepaalde cognities een rol spelen (bijv. herinnering van de vorige consumptie).

Sensorisch specifieke verzadiging (SSS) wordt niet alleen beïnvloed door intensiteit of complexiteit, maar ook door de hap-grootte waarmee een voedingsmiddel wordt geconsumeerd. In de studie beschreven in hoofdstuk 5 (*N=59*) vonden we dat *ad libitum* inname 12% lager was voor tussendoortjes in de vorm van knabbels dan voor dezelfde tussendoortjes in de vorm van repen, die met grotere happen worden gegeten [p=0.02]. Ondanks de lagere inname waren de subjectieve SSS scores gelijk tussen de knabbels en de repen [$p\geq$0.06], wat erop lijkt te duiden dat mensen sneller sensorisch verzadigd raken van knabbels dan van repen, dus sneller wanneer ze met kleine happen eten dan met grote happen.

Ook hebben we in die studie onderzocht of aandacht voor het eten de mate van sensorische verzadiging voor de tussendoortjes zou bevorderen. De resultaten bevestigen dat idee echter niet; aandacht voor consumptie had geen invloed op inname van de tussendoortjes [$p\geq$0.13], of op subjectieve SSS scores [$p\geq$0.08].

Een vergelijkbare studie in hoofdstuk 6 (*N=53*) liet zien dat eenzelfde associatie als die tussen hap-grootte en sensorisch specifieke verzadiging ook geldt voor de slok-grootte waarmee limonades worden gedronken. Inname van limonade gezoet met sucrose (energie bevattend) was 29% lager, terwijl inname van limonade gezoet met kunstmatige zoetstoffen (geen energie) 16% lager was bij drinken met kleine slokken dan bij drinken met grote slokken [beide $p<0.001$]. Ondanks de lagere inname bij kleine slokken waren de subjectieve SSS scores gelijk tussen consumptie met de verschillende slokgroottes. Deze resultaten wijzen erop dat een langdurige blootstelling in de mond sensorisch specifieke verzadiging bevordert, waarschijnlijk door een intense waarneming van de sensorische eigenschappen van het voedingsmiddel.

Daarnaast liet deze studie een verband zien tussen de ontwikkeling van sensorisch specifieke verzadiging en energie-inhoud van de limonades. Dit verband werd in eerdere studies niet gevonden. Bij consumptie met grote slokken was de gemiddelde inname van de limonade gezoet met kunstmatige zoetstoffen (geen energie) 18% [$p=0.02$] lager dan van de limonade gezoet met sucrose (energie bevattend). Bij consumptie met kleine slokken was de gemiddelde inname gelijk voor beide soorten limonade. Subjectieve SSS scores waren echter hoger voor de limonade zonder energie dan voor de energie bevattende limonade [$p=0.01$]. Meer onderzoek is nodig om deze bevinding te bevestigen en te verklaren.

CONCLUSIE

Mannen, lager opgeleide mensen, mensen die geen lijngericht eetgedrag vertonen, en mensen die gewoonlijk geen gezonde tussendoortjes eten hebben een verhoogde kans om hun intenties tot het maken van gezonde voedselkeuzes niet waar te maken. Interventies die gericht zijn op het gemakkelijk maken van de gezonde keuze moeten zich in het bijzonder richten op mannen en lager opgeleide mensen, en tot doel hebben om het maken van gezonde keuzes te bevorderen, en het gevoel van zelfcontrole te verhogen.

Sensorisch specifieke verzadiging wordt bevorderd door consumptie van intens smakende voedingsmiddelen, en voedselconsumptie met kleine happen en kleine slokken. Het aanbevelen van intense voedingsmiddelen, en het aanraden van eten met kleine happen en slokken zouden succesvolle maatregelen kunnen zijn die mensen helpen om kleine porties te eten.

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Curriculum Vitae

ABOUT THE AUTHOR

Pascalle Weijzen was born on the 17th of November 1980 in Sittard, the Netherlands. After completing secondary school at the 'Serviam Lyceum' in Sittard in 1998, she studied 'Nutrition and Health' at Wageningen University. As part of this program she carried out her internship at the University of Helsinki, Finland, in 2001. She investigated the influence of aroma level and information on the acceptance of a novel food in young adults and elderly people. For her first MSc-thesis, in 2002, she studied the associations between sporadic colon cancer and NAT2-polymorphism, diet, lifestyle, and genetic alterations. In her second MSc-thesis in 2002 she investigated the influence of complexity and flavour intensity of soups on the degree of sensory specific satiety and on their acceptance of repeated exposure. After her graduation in 2003 she started in 2004 her PhD project at the Division of Human Nutrition at Wageningen University. Her interest in the area of consumer behaviour and sensory science brought her to study the topics described in this thesis. During her PhD project she joined several international congresses and courses within the framework of the educational program of the Graduate School VLAG (Food Technology, Agrobiotechnology, Nutrition and Health Sciences). Furthermore, she was involved in the organization of a two week study tour for PhD fellows of the Division to England, Schotland, and Ireland in 2005. In 2007 she was selected to participate in the 13th European Nutritional Leadership Program. She is currently working as a researcher sensory science at Friesland Foods Corporate Research in Deventer.

LIST OF PUBLICATIONS

Full papers

Weijzen PLG, De Graaf C, & Dijksterhuis GB. Predictors of the consistency between healthy snack choice intentions and actual behaviour. *Food Quality and Preference, doi:10.1016/j.foodqual.2007.05.007. In Press*

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Weijzen PLG, Smeets, PAM, & De Graaf C. Sip size of orangeade: effect on intake and sensory specific satiety. *In preparation*

Abstracts

Weijzen PLG, Liem DG, Zandstra EH, & De Graaf C. Sensory specific satiety is related to shape of food and attention during consumption. 7th Pangborn Sensory Science Symposium 12-16 August 2007, Minneapolis, MN, USA

Weijzen PLG, Dijksterhuis GB, & De Graaf C. Healthy intentions and actual behaviour in snack choice. 2nd European Conference on Sensory Consumer Science of Food and Beverages 26-29 September 2006, The Hague, The Netherlands

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Weijzen PLG, De Graaf, C, & Dijksterhuis GB. Some choice theories compared in het light of the emotion/cognition controversy. 6th Pangborn Sensory Science Symposium 7-11 August 2005, Harrogate, UK

EDUCATIONAL PROGRAM

Discipline Specific Activities

7th Pangborn Sensory Science Symposium, Minneapolis, MN, 2007
2nd European Conference on Sensory Consumer Science of Food and Beverages, 2006, The Hague, The Netherlands
'Regulation of food intake and it's implications for nutrition and obesity' course, Wageningen, The Netherlands, 2006
'Modern Statistical Methods' course, Rotterdam, The Netherlands, 2006
'Nutrition and Lifestyle Epidemiology' course, Wageningen, The Netherlands, 2005
6th Pangborn Sensory Science Symposium, Harrogate, UK, 2005
Symposium 'Proeven van succes', Bussum, The Netherlands, 2005
Workshop 'Van goede voornemens tot daden', Maastricht, The Netherlands, 2004
WEVO (Werkgroep Voedingsgewoonten) meetings, 2004, 2005, 2006, 2007

General Courses

European Nutrition Leadership Program, Luxembourg, Luxembourg, 2007
'Career perspectives' course, Wageningen, The Netherlands, 2006
PhD Assessment, Wageningen, The Netherlands, 2005
'Organising and supervising thesis work' course, Wageningen, The Netherlands, 2005
PhD Introduction Course, 2005, Bilthoven, The Netherlands
'Presentation Skills' course, Wageningen, The Netherlands, 2005

Optional Courses and Activities

Preparation research proposals, 2005, 2006, 2007
Literature study program Human Nutrition, 2004, 2005, 2006, 2007
PhD Study Tour to England, Scotland and Ireland, 2005

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