NUTRITION INFORMATION USAGE IN FOOD CHOICES

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A collection of interdisciplinary studies, with a focus on
understanding the relation between intention and behavior

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General introduction

"Knowledge is the food of the soul" – Plato (380 B.C.)

In one of Plato's famous dialogues, the Protagoras, it was postulated that "knowledge is the food of the soul" (section 313c). The famous quote is followed by a lesser-known passage, which is translated as: "*[..] like the dealers wholesale or retail who sell the food of the body; for they praise indiscriminately all their goods, without knowing what are really beneficial or hurtful: neither do their customers know, with the exception of any trainer or physician who may happen to buy of them*." (section 313d, Jowett, 1874). So already long before this dissertation, it was apparent that merchants marketed and promoted foods towards the general public, whereas only a selected part (trainers and physicians) actually understood the information provided. Fortunately, Plato argues, that even untrained buyers can consult experts for advice before consuming anything that might be dangerous. A topic central to this dissertation.

Before delving into Plato's early conclusion that validated nutrition information needs to be used for better food choices, however, let us start from the fundament of this thesis: Food. Food is an integral part of our human existence; we need it to survive. Most essentially, we need to consume food so that our body can convert it into energy to fuel various body processes and we need to drink fluids to support our body in removing toxins, lubricating our joints, and to transport molecules from and to cells, among other things. This dissertation aims to contribute to the understanding of how we, as humans, choose the type and quantity of foods that we consume, as this has an immense impact on our health (Ng et al., 2014). In particular, it deals with the way food choices are steered by nutrition information and one's psychosocial characteristics, with a specific focus on improving our understanding of the link between one's intention to eat healthily and one's actual food intake.

In this first chapter, the relation between food and health is summarized. Subsequently, the potential to improve health through better food choices is discussed, followed by an overview of why and how nutrition information may affect food choices. In line with the aim of the dissertation, a review of the theories underpinning the effect of nutrition information, nutrition knowledge, and food related beliefs, on food choices is given, with a particular focus on understanding why there is a difference between what people say, want, and what people do – the so-called intention-behavior gap. The chapter will end with an overview of the concrete aims of the studies presented in this dissertation.

FOOD AND HEALTH

The prevalence of overweight, obesity, and related metabolic disorders and comorbidities, such as dysglycemia, central adiposity, hypertension and dyslipidemia, has risen worldwide in the past decades (Halpin, Morales-Suárez-Varela, & Martin-Moreno, 2017). The increase in these risk factors, which are called metabolic syndrome when clustered together, is a major and escalating public health and clinical challenge in the wake of urbanization, surplus energy intake, increasing obesity, and sedentary life habits (J. Kaur, 2014). In extensive meta-analyses and reviews, it has been found that lifestyle factors such as unhealthy nutritional habits, lack of physical activity, and smoking are the key contributors to this disease development (Alberti, Zimmet, & Shaw, 2005; Edwardson et al., 2012)

In this respect, an estimated 13%-17% of the European population has a BMI ≥30 kg/m^2 and can be considered obese (Gallus et al., 2015). In this group, approximately 88% has at least one of the disorders associated with metabolic syndrome (van Vliet-Ostaptchouk et al., 2014). Less at risk, but still a growing group, currently 35% of European individuals are considered overweight on average (25 kg/m^2 ≤ BMI <30 kg/m^2). Particularly gender (males), low education, and low incoming are associated factors with overweight and obesity (Gallus et al., 2015). In the Netherlands alone, 43% of individuals are considered overweight, while 12% are considered obese (Statline, 2016). As such, there is a tremendous push to improve nutritional habits to reduce obesity/overweight and reduce the prevalence of metabolic syndrome (WHO, 2017). Moreover, in Europe, there has been an increased interest in identifying the precise antecedents that could predict diseases related to metabolic syndrome, including nutrition-related behavior (Scuteri et al., 2014).

In light of this emerging problem, various strategies have been proposed to prevent the development of metabolic syndrome. These include increased physical activity (such as being physically active for at least 30 minutes every day) (Gezondheidsraad, 2017; Lakka & Laaksonen, 2007) and a healthy diet (Andersen & Fernandez, 2013). Healthy diets, in turn, are proposed to be comprised of foods that provide roughly the same

amount of energy that your body is using to maintain a healthy weight, are limited in (saturated) fat, salt, and sugar, and consist for a large part of plant foods, particularly fruits, vegetables, legumes, whole grains and nut (WHO, 2013). In addition, specific "functional foods" (e.g., Omega-3 enriched butter) are being developed by food industry, which contain ingredients that are explicitly included for health-promotion or disease prevention (Bech-Larsen & Grunert, 2003).

FOOD CHOICES

While the guidelines proposed by the World Health Organization (WHO, 2013) or local governments (Voedingscentrum, 2016) provide concrete recommendations of which foods or groups of foods should be consumed, there is still a tremendous variance between individuals in terms of diet composition. In many studies, it has become clear that this variance is strongly correlated with functional and metabolic efficiency, and thus with health (Jallinoja, Niva, Helakorpi, & Kahma, 2014; Jankovic et al., 2014; Swinburn et al., 2011). Based on a national food consumption survey conducted between 2012 and 2014, there is insufficient compliance with the dietary guidelines in the Dutch population, for example. On average, only 15% of adults eat the recommended amount of 200 grams of vegetables a day, and only 6% of adults eat the recommended 15 grams of nuts or more a day (Van Rossum et al., 2016; Van Rossum et al., 2017).

So in spite of the clear detrimental consequences of consuming unhealthy foods, which mostly are low satiating, energy-dense, and have non-adequate quantities of micronutrients, consumers are still often engaging in food consumption behavior that negatively impacts their well-being (Swinburn et al., 2011). In this respect, it is infered that there is a causal role for food advertising in the etiology of the global obesity and metabolic syndrome epidemic, as advertisers have effectively used insights from research to shape what people eat using in-store and near-store promotions (Chandon & Wansink, 2011). In addition, both physiologically (Breslin, 2013), and psychologically (Raghunathan, Naylor, & Hoyer, 2006), foods and beverages containing high amounts of fat and simple sugars have a high hedonic value, resulting in subliminally activated taste inferences and increased palatability. To put it blunty; unhealthy foods just appear to taste better for some.

Still, consumers also can make food choices for long-term health benefits, rather than the immediate gratification of a preferred taste. Apparently, sometimes consumers understand better the effects of adequate nutrition on health and value this highly (Wansink, 2005), and/or they can control their visceral urges for indulgent decisions (Yang et al., 2012). It seems that when the long-term reward of a healthy life is considered, it could outweigh the short-term reward of better taste. Often, however, the value of such a distant reward is subconsciously discounted – an immediate reward

(e.g. the nice taste of a medium-rare beef steak) is perceived more valuable than a later reward (e.g., reduced risk of cancer) (Soman et al., 2005). This delayed reward discounting, and the rate by which this occurs, is a well-studied phenomenon and controlled experiments have been conducted on how it can be influenced by, for example, blood glucose level (X. T. Wang & Dvorak, 2010) and erotic stimuli (Van den Bergh, Dewitte, & Warlop, 2008).

A psychological account to explain the varying preference for smaller-sooner rewards over larger-later rewards, and thus the results of these experiments, is given through the dual-process theory (Hofmann, Rauch, & Gawronski, 2007; Price, Higgs, Maw, & Lee, 2016), which emphasizes that people have the capacity to engage in calm, controlled, and rational thinking, as well as emotional, impulsive and automatic reactions (using heuristics) when given a task or a food choice (Scharff, 2009). When cognitive capacity is limited (e.g., because of a low blood glucose level), people tend to engage more in impulsive reactions and choose smaller-sooner over larger-later rewards. When making quick and impulsive food choices, people's decisions are the result of simple heuristics (i.e., rules of thumb) that people use and are generally only based on a few important pieces of information. While more deliberative and rational choices are the result of taking many different aspects into account and weighing them according to ones personally assessed importance (Chance, Gorlin, & Dhar, 2014; Scheibehenne, Miesler, & Todd, 2007)

In this thesis, we take a divergent approach than the dual-process theory to understand better how food choices are dependent on the nutrition information that is obtained and comprehended, as this correlates with outcome expectancies and risk perceptions, among other things (Schwarzer & Luszczynska, 2008). By taking a more interdisciplinary approach, which we detail further, we can take into account an array of other factors that influence healthy food choices that have been identified throughout the literature. The European Food Information Council, in this respect, provided a nice structure of the various research streams associated with this topic and listed the major determinants of healthy food choices as follows (EUFIC, 2006):

- Biological determinants (e.g., hunger and taste)
- Economic determinants (e.g., cost and income)
- Physical determinants (e.g., proximity of supermarkets)
- Social determinants (e.g., culture and family)
- Psychological determinants (e.g., mood and stress)
- Attitudes, beliefs and knowledge about food

In a recent summary of the state-of-the-art in this field which included above determinants (Leng et al., 2016), the interdisciplinary nature of this field was further emphasized. It should be noted that food choice factors also vary according to life stage and that the determinants will vary from one individual or group of people to the next.

Moreover, legislation related to foods and food labelling can have a determining role in a consumers' food choices.

NUTRITION INFORMATION AND NUTRITION LITERACY

Nutrition information can be obtained through various sources. These sources include, for example, parental advice, TV commercials, social media, health magazines, and food labels (Grunert & Wills, 2007). According to a recent systematic review (Liberato, Bailie, & Brimblecombe, 2014), providing adequate nutrition information on food labels could be a cost-effective method of communicating nutrition information to consumers because the information appears at the point of sale. In this respect, there has been a strong focus on providing consumers with appropriate information of the nutritional composition of food products through labelling. With EU regulation 1169/2011 on the provision of food information to consumers (EC, 2011), standards to provide such information were increased "in order to achieve a high level of health protection for consumers and to guarantee their right to information" (p. 18). Food labels, in this respect, often include nutritional tables, ingredient lists, and sometimes nutrition and health claims.

Nutritional tables provide information on calories and amounts and/or daily values of several macronutrients and minerals (e.g., fats, carbohydrate, salt). Ingredient lists provide an account of ingredients in descending order of proportion by weight. These ingredient lists can elucidate the presence or absence of specific components (e.g., whole grain or refined grain). Nutrition claims may communicate the value or relative amount of a specific nutrient within a food product (e.g., good source of fiber, fat-free), while health claims are intended to communicate scientifically proven health benefits associated with consuming a particular food (e.g., "food high in vitamin C increase iron absorption") (Miller & Cassady, 2015).

Regardless of the source of nutrition information, the consulting and interpretation of this information by the consumer depends on many factors – and has been widely studied in various contexts (Berning, Chouinard, & McCluskey, 2008; Ebneter, Latner, & Nigg, 2013; Graham, Orquin, & Visschers, 2012; Grunert, Fernández-Celemín, Wills, Storcksdieck, & Nureeva, 2010; Lähteenmäki, 2014; Miller & Cassady, 2015). Particularly among the general European public, it was found that consulting information on food products conflicts with the consumers' reluctance to engage in deliberation when buying food (Grunert et al., 2010). Consumer food decision-making is mostly simple (i.e., only a few pieces of information are used), fast (i.e., as little as 0.313 seconds per choice according to one study (Mormann, Koch, & Rangel, 2011), and based on acquired habits. As such, consumers often disregard nutrition information on food labels, but also from other sources. Moreover, even when consulted, the nutrition information provided can be interpreted incorrectly (Lähteenmäki, 2014).

In a recent review (Miller & Cassady, 2015), evidence on nutrition information usage in making food choices and dietary intake was summarized. Across the reviewed studies, a strong association between attention to nutrition information, nutrition knowledge, and healthy food choices was found. As such, it has been suggested that nutrition knowledge can be expressed as nutrition literacy – a relatively new concept, adapted from the term health literacy (Zoellner, Connell, Bounds, Crook, & Yadrick, 2009). Nutrition literacy, in this respect, is defined as the degree to which people have the capacity to process, and understand basic nutrition information (Zoellner et al., 2009). Miller and Cassady conceptualized that nutrition information usage can be split in attention and comprehension to nutrition information. In Figure 1, this split is visualized in a simplified model of the processes underlying use of nutrition information.
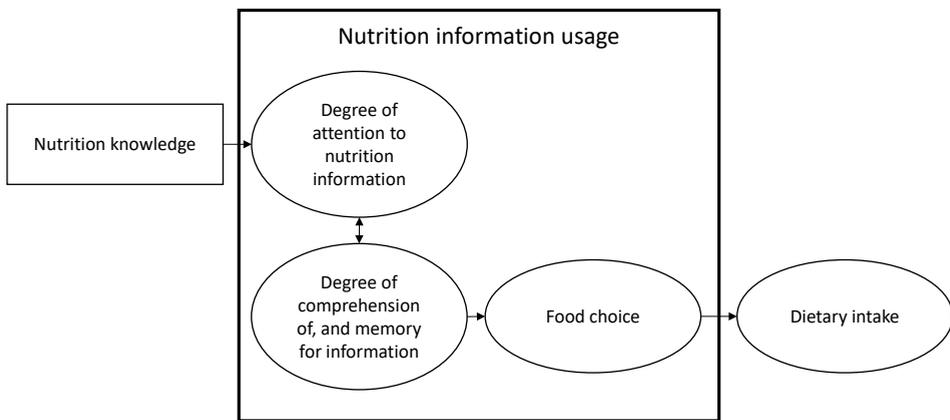
Figure 1: Cognitive processes underlying use of food labels as adapted from Miller and Cassady (2015)

In their conclusion, Miller and Cassady argued that nutrition knowledge likely helps by directing attention to salient information, promoting comprehension, allowing more accurate information to be stored in memory and used in decision-making situations. They provided support for the notion that food label use relies on a set of interrelated processes centered in cognitive psychology.

In summary, even if consumers consult nutrition information, it is often interpreted incorrectly, or miscomprehended. Through low nutrition knowledge, the extent to which people have the capacity to process nutrition information, consumers are often not able to categorize foods according to the amount and frequency with which they should be consumed (Pendergast, Garvis, & Kanasa, 2011).

PROBLEM STATEMENT

Although strong legislation resulted in the inclusion of clear, harmonized and legible provision of nutritition information through food labels to consumers, the impact on health has been very limited (Lachat & Tseng, 2013; Patterson, Bhargava, & Loewenstein, 2017). While people in Europe and other industrialized countries are becoming more conscious about factors influencing their personal health (Brannon, Feist, & Updegraff, 2014; Bugge, 2015), there is still a lack of sufficient nutrition knowledge to ensure that healthier food choices are made. Moreover, attention to and correct interpretation of nutrition information does not result in correct food choices.

There is evidence that even health-conscious consumers, estimated to be over 50% of the European population (Jallinoja et al., 2014), often do not make dietary choices that benefit their health. It appears that there is a mismatch between a person's health-consciousness, their intentions, and the actions following these intentions (Stroebe, Van Koningsbruggen, Papies, & Aarts, 2013). For example, with the intention of eating healthier, health-conscious consumers have avoided the consumption of products containing fructose (Welsh, Sharma, Grellinger, & Vos, 2011) or products containing wheat (Brouns, van Buul, & Shewry, 2013). Both these actions do not result in an overall healthier diet in the general population as fructose-free or wheat-free products do not provide additional health benefits from a nutritional perspective (Missbach et al., 2015; Willett, 1994). We aim to study this problem through the lens of behavioral psychology to aid development of effective interventions.

In summary, available nutrition information is often used limitedly, or used incorrectly, in making food choices. Moreover, through a plethora of factors discussed in a wide array of research streams, European consumers make unhealthy food choices, despite having a long-term goal of consuming healthy foods. Therefore, in this dissertation, interdisciplinary studies on the way food choices are steered by nutrition information are reported, with a specific focus to improve our understanding of the link between intention and behavior. In a study reported in Chapter 4 and 5 of this dissertation, we confine our study to consumers who have an intention to eat healthily. This group is already motivated to become healthy, something which is often a hard-to-convey prerequisite for healthy behavior. Essentially, they "just" need to make the healthy food choices. This thesis will focus on the factors that possibly attribute to the misfit between healthy diet intentions and behavior using an interdisciplinary perspective.

BEHAVIORAL HEALTH PSYCHOLOGY

We use a systematic approach to study the problem at hand. In this regard, to guide the enterprise of finding facts, we build further on theories postulated in the field of

behavioral health psychology. By using a solid theoretical framework, impactful interventions can be developed that target the most important psychosocial factors associated with healthy food choice behavior (Brug, van Assema, & Lechner, 2017).

In this scientific field, particularly the precede-proceed model (Green & Kreuter, 2005) and the intervention-mapping protocol are prevailing models for systematic intervention development (Bartholomew, Markham, Ruiter, Kok, & Parcel, 2016). Both propose the following steps:

1. Analyzing the health problem
2. Analyzing the behavior
3. Analyzing the determinants of behavior
4. Developing an intervention
5. Intervention implementation and dissemination

The research in this dissertation is focused on the third step, wherein we analyze the determinants to behavior related to a health problem. In this respect, we focus particularly on how people select the food they eat. A multidisciplinary topic, food choice comprises psychological and sociological aspects (including food politics and phenomena such as vegetarianism or religious dietary laws), economic issues (for instance, how food prices or marketing campaigns influence choice) and sensory aspects (such as the study of the organoleptic qualities of food).

Daily food consumption decisions – choices about both the quality and quantity of food that is ingested – can also be studied through behavioral psychology. For instance, using the theory of planned behavior, models have been proposed to predict fruit and vegetable intake (Bogers, Brug, van Assema, & Dagnelie, 2004; Kothe & Mullan, 2015). In these so-called social cognitive theories and models, it is assumed that intention to behave is a powerful determinant of actual behavior. In terms of predicting fruit and vegetable intake, for example, there is abundant evidence of this intention-on-behavior effect. In one study among Italian students, it was found that 81% of the variance of fruit and vegetable intake was associated with the student's self-reported intention to eat more fruits and vegetables (Menozzi, Sogari, & Mora, 2015). Another study, however, reported that only 32% of the variance in intention was associated with fruit and vegetable intake (Povey, Conner, Sparks, James, & Shepherd, 2000). In a systematic review that pooled multiple studies using models derived from the theory of planned behavior found that, when data was combined, 45% of fruit and vegetable intake was associated with ones intention to eat more fruits and vegetables (Guillaumie, Godin, & Vézina-Im, 2010).

In the problem introduced above, we already highlighted that people's food choice behavior sometimes is not directly in line with their intentions. Sometimes, there is a difference between what people say, want, and what people do – particularly in complex food choices such as refraining to eat all products with wheat. In this regard,

models have focused on other predictors for healthy food choice behavior, which address this so-called intention-behavior gap.

Intention-behavior gap

A behavioral intention indexes a consumer's *motivation* to perform a certain behavior. Such intentions can encompass both the direction (e.g., to increase/decrease overall food intake) and the intensity (e.g., 100kcal/day) of food consumption decisions (Sheeran, 2002). As explained, there can be an inconsistency between this intention and actual behavior. It is known that there is a strong situational effect on the intention-behavior gap (Ajzen, 1985). For example, next to a plate of fresh-baked cookies, it can be hard to behave in accordance with an intention to refrain from snacking.

As can be expected, there is also a strong heterogeneity between people in how well intentions are translated into behavior (Radtke, Kaklamanou, Scholz, Hornung, & Armitage, 2014). Moreover, in various studies (Papies, 2017; Sheeran et al., 2016), it is underlined that the specific type of behavior (e.g., condom use, exercise, etc.) has a significant influence on the degree of the intention-behavior gap. So not only from person-to-person, also from behavior-to-behavior, there are many fluctuations in how intention is translated into action.

Healthy food choice behavior, in this respect, can be seen as a single action (e.g. eating 2 pieces of fruit per day) or more a holistic goal for which a complex array of actions, psychosocial factors, and environmental cues are at interplay (e.g., reading and comprehending nutrition information to make healthy choices in line with current scientific evidence). With this in mind, different models have been developed that take into account the various factors that could distort this intention-behavior gap, and to increase model-fit for specific behaviors. An important variable mentioned in such models for health behavior is planning (de Vries, Kremers, Smeets, Brug, & Eijmael, 2008; Schwarzer, 2008). It has been found that good intentions are more likely to be translated into action in the case that people plan when, where, and how to perform the desired behavior (Sniehotta, Schwarzer, Scholz, & Schüz, 2005). Intentions foster planning, which in turn facilitates behavior change. As such, planning was found to mediate the intention-behavior relation in cardiac rehabilitation, for example (Sniehotta, Scholz, & Schwarzer, 2006).

Next to planning, other factors could influence the intention-behavior relationship. Perceived self-efficacy and self-regulatory strategies (action control) have also been found to mediate between intentions and behavior (Sheeran, 2002). Moreover, the quality of the intention itself matters, according to a recent review of the literature on this topic (Sheeran & Webb, 2016). In summary, to translate intention to behavior, people need to initiate, maintain, and close goal pursuit. Factors that possibly influence this relationship will be addressed in the paragraphs below.

The Health Action Process Approach model

One of the models that focusses on planning in the intention-behavior gap, and that leaves room for factors such as nutrition literacy and self-efficacy (i.e., factors that are known to be important in dietary behaviors (Godinho, Alvarez, & Lima, 2013; Lippke & Plotnikoff, 2014) is the health action process approach (HAPA) model (Schwarzer, 1992). HAPA reflects a stage model to describe how individuals move through a pattern of distinct phases when setting and acting on an intention to become healthier (Brug et al., 2017). The HAPA model acknowledges that there are many factors that could distort the translation between intentions to behavior, and thus provides for a good starting point to help understand our research question.

   In essence, the HAPA model is a social-cognition model that describes the key stages and cognitions related to acting on an intention. Contrary to some of the other social-cognition models, it has been explicitly developed to focus on health behavior change, and is designed to be an open architecture framework – so that determinants can be added to increase its fit to particular health problems. According to the model, through a motivation and volition stage, people can develop intentions to be more healthy (motivation) and subsequently act on these intentions (volition). In this volition phase, one can distinguish two groups of individuals: those who have not yet translated their intentions into action (intenders), and those who have (actioners). A simplified version of the HAPA model is depicted in Figure 2.

   In the model, three key constructs that lead to behavioral intention are mentioned: risk perception, outcome expectancies and self-efficacy. In a study by Renner and Schwarzer (2005) using the HAPA model, the process of forming intentions in the context of healthy eating was described. In a sample of 1782 men and woman, the authors showed that becoming aware of the risks of unhealthy eating (i.e., hypertension, heart disease, etc.) is often the initial driver to form any intention. Outcome expectancies (i.e., the expected consequences of eating healthier) and perceived self-efficacy (i.e., an individual's beliefs in their capability to execute plans), however, were found to be the most influential factors in intention formation (Schwarzer, 2008; Sheeran, 2002; Sheeran & Webb, 2016).
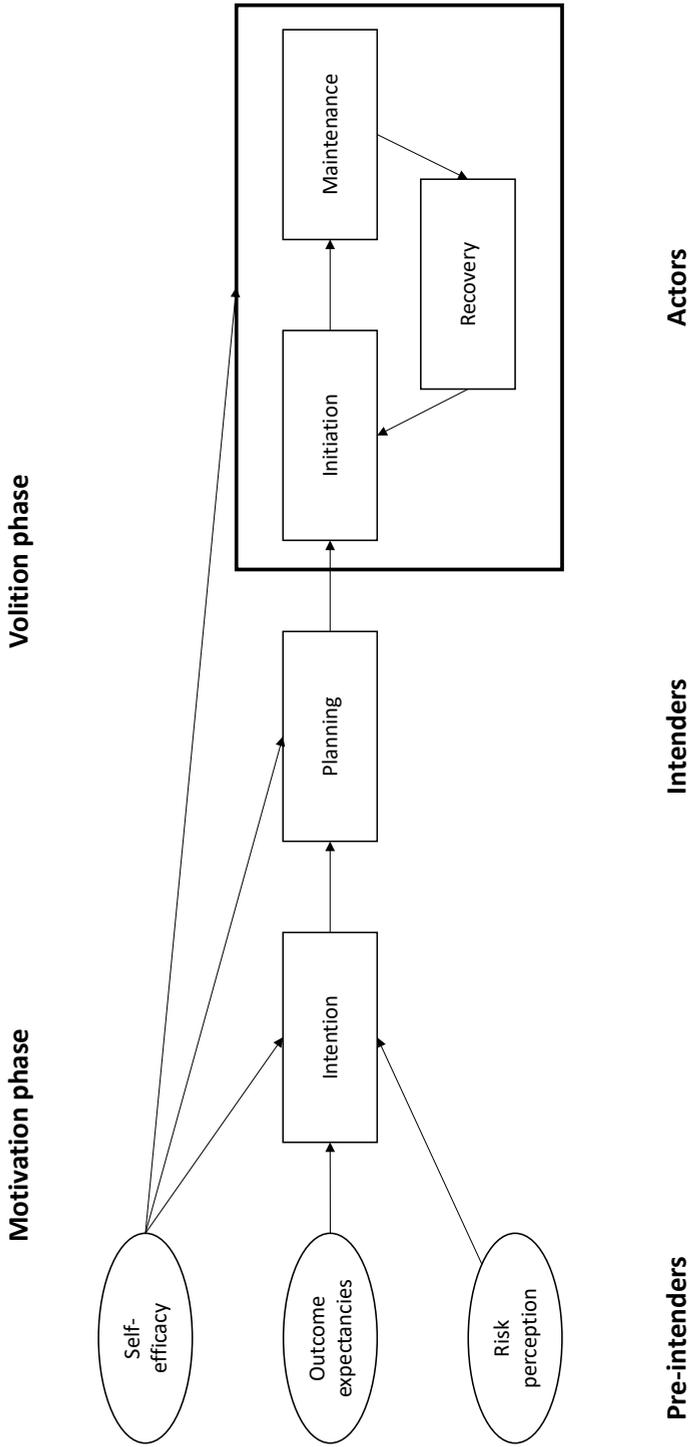
Figure 2: Simplified model of the health action process approach (adapted from Schwarzer (1992), showing the two main phases on top and three main groups of people in the bottom

In the context of the present work, we focus on consumers who have a positive intention to eat healthily. These consumers are able to perceive the risk of unhealthy food consumption, understand the expected outcomes of changing behavior and believe that they are capable to exercise control of their actions with respect to healthy food choices (Lippke & Plotnikoff, 2014). They have surpassed the pre-intention phase, have the intention to eat healthily, and are thus in the volition phase. In this volitional phase, however, we can distinguish a subset of people (*intenders*) who have the intention to eat healthier, but do not translate this into concrete plans that are followed by behavior (Schwarzer, 1992). Within the HAPA model, we can compare this group with the second group of individuals in the volition stage: the *actors*. A crucial difference between the two groups is the ability to make post-intentional plans and enactment of these plans (de Vries, Eggers, & Bolman, 2013; Sniehotta et al., 2006). Such plans are characterized by developing scenarios and preparatory strategies for reaching a goal, as well as anticipation of barriers and the generation of alternative behaviors to overcome these barriers (Schwarzer, 2008).

We assume that these *intenders* and *actors* are characterized by different personal characteristics and social cognitive beliefs when making food consumption decisions. For instance, we expect an influence of socio-economic status, nutrition, health, and traditional literacy (including oral literacy), but also other factors including confidence, self-efficacy, self-control and personal consumption norms, as found in a plethora of research (Conner & Norman, 2015; Lippke, Ziegelmann, Schwarzer, & Velicer, 2009; Wansink, Just, & Payne, 2009). In a recent systematic review (Vaitkeviciute, Ball, & Harris, 2015), evidence on a positive association between the level of food information processing and adolescents' dietary intake was summarized. Although the available evidence was not conclusive due to lack of rigor in the reviewed studies, the authors posited that nutrition literacy might play an important role in shaping food intake decisions. Hence, Vaitkeviciute et al. (2015) concluded that nutrition literacy (termed food literacy in their review) needs to be included in models assessing food choices. Given the complexity of holistic goal-oriented behavior, this additional construct is necessary to conceptualize the translation of intention to behavior.

STRUCTURE OF DISSERTATION

This dissertation will take an interdisciplinary approach to better understanding of the way nutrition information affects food choices, with a specific focus on the link between intention and behavior. The research consists of two parts. In the first part, we address two specific cases were food consumption decisions were steered by information about single components of food (EU approved health claims in chapter 2, and fructose-containing sugars in chapter 3). Through narrative reviews, we argue that there might

be better ways to let people engage in healthy nutrition behavior, and that alternative models should be considered to view the problem of unhealthy eating.

In chapter 2, an answer will be provided on the question:

> How do European consumers perceive nutrition and health claims about specific food ingredients and how to improve the attention to and comprehension of such claims?

In chapter 3, a case study is presented in which nutrition information provided by various stakeholders is not in line with scientific findings. In particular, an answer will be provided on the question:

> Why are recommendations to reduce fructose-consumption disputable and impractical given the current scientific findings on the relation between fructose and obesity?

To help understand the concepts and their (proposed) relationships, we created the conceptual model depicted in Figure 3. Adapted from the traditional HAPA model (Schwarzer, 1992), it focuses on the specific factors influencing the relation between an intention to eat healthily, and the level of action-plans formed to reach this goals. As introduced, when good intentions are translated into plans, the desired behavior is more often performed (Martiny-Huenger, Bieleke, & Gollwitzer, 2016; Richert et al., 2010). It includes the position of the cases described in Chapter 2 (nutrition and health claims) and in Chapter 3 (recommendations about fructose-containing sugars), which both address how intentions are formed, and how they are translated into action under the influence of marketing and scientific health recommendations.
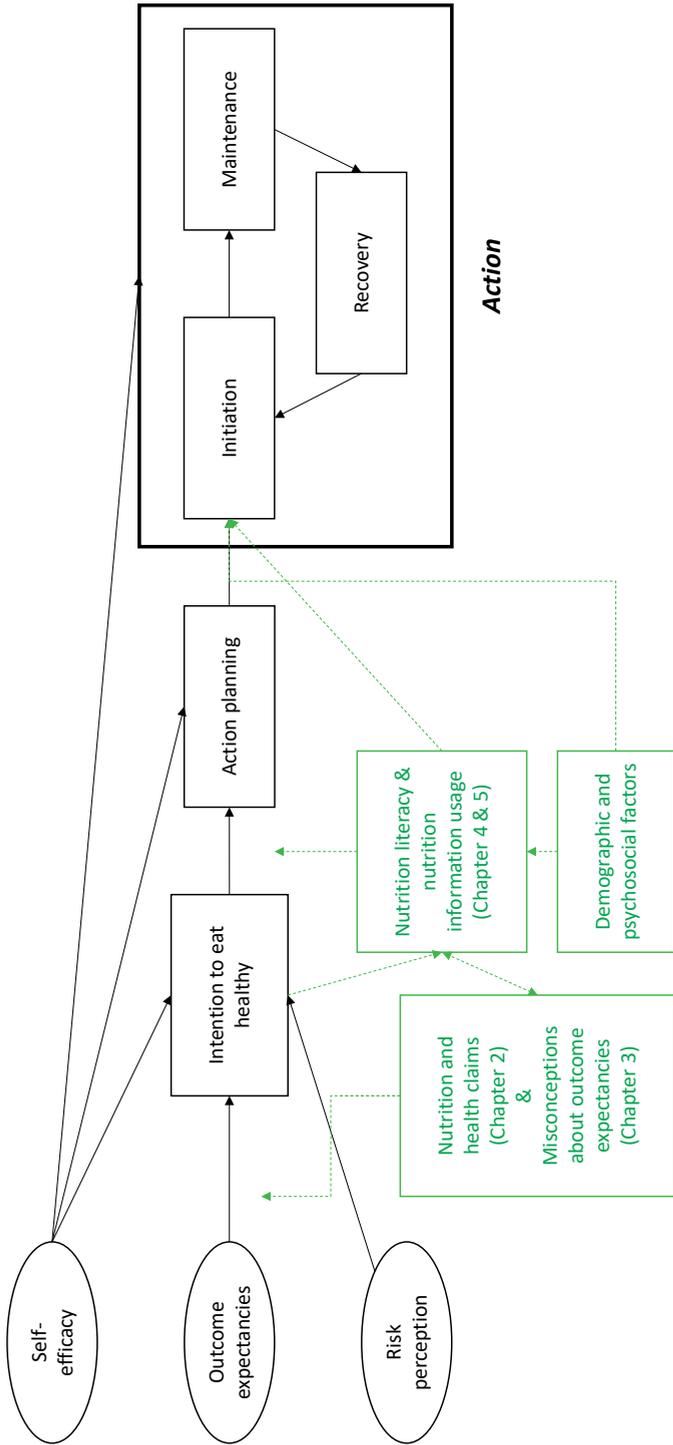
Figure 3: Conceptual model of the research, with contributions to the simplified HAPA model in green.

In the above conceptual model, we add constructs that could affect a consumer's intention to eat healthily, and the translation of these intentions to action planning. We separate nutrition literacy as a separate construct that influences how well intentions are converted into action, and add the role of demographic and psychosocial factors. In chapter 4 of this dissertation, this role is further discussed using data obtained from a cross-sectional survey in individuals who intend to eat healthily. Using process tracing software in a computerized task in which participants had to make dichotomous food choices, we measured the frequency and time of categories of nutritional information considered. By monitoring the actions preceding their food choice behavior, we might be able to improve the model to study food choice behavior in consumers who have the intention to eat healthily.

As such, in chapter 4, an answer will be provided on the question:

> What are the determinants of inadvertent (un)healthy substitutive food choices from consumers who have the intention to eat healthily?

Using the data-set described in chapter 4, we are also able to form groups of consumers, who cluster on food contents of energy, salt, sugar, and saturated fat considered to investigate differences, as hypothesized in our conceptual model. We investigate if consulting information on these "four evils" leads to healthier choices. Moreover, we investigate if there are sub-groups of consumers that can be characterized by means of demographic and psychosocial variables to improve future interventions.

As such, in chapter 5, an answer will be provided on the question:

> *What are differences in demographic variables, psychosocial variables, nutrition literacy scores, and taste preferences between groups of consumers who intend to eat healthily, segmented on the time and frequency of energy, salt, sugar, and saturated fat information usage?*

Jointly, answering these questions will contribute to our knowledge on the extent to which nutrition information is considered, and the kind of information that influences behavior and food choice. Particularly, by looking into why nutrition information is not actively consulted by consumers, and even if consulted, how it is sometimes comprehended incorrectly, we can focus on what the determinants are of healthy food choices.

The scope of this research by no means includes to find all factors relevant to the quality of the average diet. We acknowledge the wide range of disciplines involved in food consumption behavior, and especially also consider alternative paradigms from the natural sciences – particularly in the first two chapters of the dissertation next to the more traditional social cognitive behavioral explanation models.

Despite the limited scope of our research, our results will likely induce a wide range of promising avenues for future study. By giving insight into the problem of unhealthy food consumption, and looking at the lenses that we use to view this problem, we hope to stimulate better (inter)national policies that promote comprehensible and effective sources nutrition information, that are developed using learnings from health psychology, in addition to epidemiological data.

Chapter 2

Nutrition and health claims as marketing tools

ABSTRACT

European regulations mandate that only substantiated and approved statements can be used as nutrition- and health-related claims in food marketing. A thorough understanding of consumer perceptions of these approved claims is needed to assess their impact on both the purchase intention of functional foods and the development of innovative functional food concepts. In this paper, a conceptual framework on the European consumers' perception of nutrition and health claims on these functional foods is proposed. Through a literature review, common independent variables are structured, and an analysis of these variables shows that nutrition and health claims are mostly only perceived positive by specific target consumers (who need the product, accept the ingredient, understand the benefit, and trust the brand). These consumers indicate that the products with substantiated and approved claims help them in reaching overall health goals. This increased expectation in functional efficacy may mediate an increase in repurchase intent, overall liking, and the amount consumers are willing to spend. Other consumers, however, may have adverse reactions towards nutrition and health claims on functional foods. Implications for the consumer and the industry are discussed.

INTRODUCTION

The current concerns about the impact of diet on health are reflected in the growing economic and social costs associatied with diet-related illnesses such as cancer, diabetes, and cardiovasular disease (Amine et al., 2011). The national authorities in the European Union are focusing more and more on cost-effective health care, where the importance of lifestyle and dietary changes for improved health and disease prevention are well-established (Mhurchu, 2010). Hence, in order to adress these dietary changes, attention has focussed on the development of numerous functional foods (FFs) by food manufacturers. These FFs are purported to contain health-promoting ingredients. According to the European Commission (EC), general principles and regulations were to be established for these claims in order to ensure a high level of consumer protection, give the consumer the necessary information to make choices in full knowledge of the facts, and create equal conditions of competition for the food industry, as well as stimulate innovation (EC, 2006a). Furthermore, these principles and regulations would strenghten consumer confidence in nutrition and health claims (NHCs), which is a critical concern for both the manufacturer and the consumer. Well-substantiated NHCs should help consumers to make informed choices, as well as help them identify particular foods and food components with health benefits.

This chapter focuses on consumer perception of these NHCs and on how these claims and the presence of functional ingredients influence consumer evaluation and purchase intent of FFs. These findings provide relevant information for FF manufacturers and consumers alike.

Background

Throughout shopping sessions, consumers come across different products that carry different label information. Manufacturers often include claims on their products to advertise and set apart their goods from competitors. In this respect, Apple's new iPad now claims to have "over 200 new features" and McDonald's chicken snacks are claimed to be "extra crispy". In the field of linguistics, these claims are defined as declarative propositions which can either be true or false (Long, Oppy, & Seely, 1997). Back in 1985, most of these claims on food were related to their sensory aspects, and only 10.4% of all claims were related to nutrition and health. Today's food manufacturers are rapidly shifting to nutrition and health related claims. For example, in a recent study in the United States, 65% of claims made on food were classified as NHCs (Kim, Cheong, & Zheng, 2009).

Currently, European legislation directs marketers who use NHCs to provide precise, scientific, and substantiated information on the functional ingredients being used and their potential health benefits. For the purpose of this article, we will focus on the

growing market of FFs that use health claims and/or specific nutrition information to differentiate themselves from competitive products.

Research contribution

This topic explores different fields of marketing, consumer behavior and psychology research. Because NHCs are heavily interlinked with marketing research on FFs, the conceptual background of this review will include research on:

- The *need* for FFs and FBs (Aschemann-Witzel & Hamm, 2010; Landström, Koivisto Hursti, Becker, & Magnusson, 2007; Menrad, 2003),
- The *acceptance* of functional ingredients in these foodstuffs (Tuorila & Cardello, 2002) (Ares & Gámbaro, 2007; Siro, Kápolna, Kápolna, & Lugasi, 2008; Vidigal, Minim, Carvalho, Milagres, & Goncalves, 2010)
- The *understanding* of NHCs (Agrawal & Wan, 2009; Andrews, Netemeyer, & Burton, 1998; Fernández Celemín & Grunert, 2012; Leathwood, Richardson, Strater, Todd, & van Trijp, 2007; Mariotti, Kalonji, Huneau, & Margaritis, 2010; Richardson, 2005; Van Kleef, van Trijp, & Luning, 2005; Williams, 2005)
- And whether consumers *trust* the health related claims (Bech-Larsen & Grunert, 2003; Bech-Larsen & Scholderer, 2007; Siegrist, Stampfli, & Kastenholz, 2008; Verbeke, Scholderer, & Lähteenmäki, 2009; Zwier, 2009).

These four factors; need, accept, understand and trust can be aligned with an approach by Wennström (2000, 2009) and Mellentin (2002) who discuss the marketability of FFs. The data indicate that most consumers only look at NHCs on products for a very short time (< 4 seconds), which is insufficient for extensive processing of information (Fernández Celemín & Grunert, 2012), and that actually only 7 to 10 percent can recall looking at the claim (Aschemann-Witzel & Hamm, 2010; Fernández Celemín & Grunert, 2012). This suggests that it is important that novel consumer research focuses on understanding the consumer perception of the presence of NHCs rather than the consumer understanding of particular NHC wordings.

European regulatory status of nutrition and health claims

Multiple large-scale projects preceded changes in the European regulatory landscape, which intended to help consumers to make the right food choices. The Functional Foods in Europe (FUFOSE) and Process for the Assessment of Scientific Support for Claims on Foods (PASSCLAIM) projects underpinned the laws and provided criteria against which the quality of the totality of the available data could be judged (Richardson, 2012). By tightly regulating what can, and cannot, be claimed on a foodstuff, the EU followed internationally recognized standards for food labeling as set out by the Codex

Alimentarius Commission on Food Labeling (CA, 2001). To claim the presence or absence of certain substances in foods, the food manufacturer can use a nutrition claim (NC) on the packaging. To claim a relation between an ingredient and a health benefit from that ingredient, a health claim (HC) can be used. The conditions of use for these claims are regulated in Europe by Regulation (EC) no 1924/2006 (EC, 2006a).

The academic community has discussed the implications of this regulation thoroughly. Some argue that the regulation places greater burden on food manufacturers' research and development resources (Leathwood et al., 2007). The strict conditions of use for NHCs are based on recommendations by the Panel on Dietetic Products, Nutrition, and Allergies (NDA) of the European Food Safety Authority (EFSA). EFSA-NDA panelists Verhagen, et al. (2010) reviewed the status of the relevant regulation concerning both NCs and HCs in Europe and note that consumers make "only little or no distinction between nutrition and health claims". However, according to the 'new' definitions as set out by Regulation (EC) no 1924/2006 of the European Parliament and of the Council, of 20 December 2006, there is a clear distinction between nutrition and health claims made on foods (EC, 2006a). The food manufacturers and product developers understand this difference greatly. The costs in research and development efforts, reformulation, marketing efforts, and regulatory affairs, are much higher when the use of a HC is desired compared to NCs. Moreover, a development process which includes the substantiation of health benefits to consumers greatly reduces the speed to market compared to a NC (Wollgast, 2011).

The objective of Regulation (EC) no 1924/2006 was to harmonize the national rules on NHCs. Whilst ensuring the free distribution and sale of foods, it also provides a high level of consumer protection. Furthermore, it aimed to permit consumers to choose products in full understanding of the facts and to ensure fair competition. The scope of the regulation is to include all aspects of food products made in commercial communications to the final consumer: labeling, descriptive presentation, advertising, and in some cases brand names, and trademarks.

Claims are generally defined as "any message or representation, which is not mandatory under Community or national legislation, including pictorial, graphic or symbolic representation, in any form, which states, suggests or implies that a food has particular characteristics"(EC, 2006a).

According to Article 3 and 6 of the regulation, these claims shall (a) not be false, ambiguous or misleading; (b) not give rise to doubt about the safety and/or the nutritional adequacy of other foods; (c) not encourage or condone excess consumption of a food; (d) not state, suggest or imply that a balanced and varied diet cannot provide appropriate quantities of nutrients in general; (e) refer to changes in bodily functions which could give rise to exploit fear in the consumer, either textually or through pictorial, graphic or symbolic representations. Furthermore, all claims need to be based on and substantiated by generally accepted scientific data (EC, 2006a; Verhagen et al., 2010). It should be noted that the words "generally accepted" are rather vague, in this

respect. The regulation, however, does put forth clear definitions of the different categories of claims wherein a NC is defined as follows (EC, 2006a, Art. 2(4)):

> "'nutrition claim' means any claim which states, suggests, or implies that a food has particular beneficial nutritional properties due to: (a) the energy (calorific value) it (i) provides; (ii) provides at a reduced or increased rate; or (iii) does not provide; and/or (b) the nutrients or other substances it (i) contains; (ii) contains in reduced or increased proportions; or (iii) does not contain;"

HCs are defined broader (EC, 2006a, Art. 2(5)):

> "'health claim' means any claim that states, suggests or implies that a relationship exists between a food category, a food or one of its constituents and health;"

Then, there is a separate definition for a specific type of HC, the reduction of disease risk claim (EC, 2006a, Art. 2(6)):

> "'reduction of disease risk claim' means any health claim that states, suggests or implies that the consumption of a food category, a food or one of its constituents significantly reduces a risk factor in the development of a human disease;"

The regulation continues to set out different subcategories of NCs and HCs, which are conveniently overviewed in Table 1, modified from Verhagen, et al. (2010). Within this table, one can see that the NCs are subdivided into content claims and comparative claims. HCs are subdivided in function claims and reduction of disease risk claims, where the former are again subdivided in the so-called article 13(1), and article 13(5) claims. Note that the examples are all substantiated claims and, under certain conditions, can be used on food packaging (Gilsenan, 2011).

New article 13(5) and article 14 claims are based on newly developed (proprietary) data, and to use such claims a substantiation document has to be submitted to EFSA (EC, 2006a, Art. 15). Within this document, companies have to prove a causal relationship between the ingredient and the proposed beneficial effect. In many cases, a substantial number of controlled nutrition intervention studies are required to obtain conclusive evidence. Consequently, there are high costs involved to get a new claim approved. Both NCs and article 13(1) HCs are compiled on approved lists. On these lists, you can find the claim and the conditions that apply to use such a claim. Interestingly, in both categories the European Commission also approves claims that are likely to have the same meaning for consumers. This upholds a certain degree of flexibility in the NHC wording for the manufacturers. An example of the conditions of use for a NC, which are given on the approved list for NCs, is given below:

Table 1: Overview of nutrition and health claims in regulation (EC) no 1924/2006

	Regulation (EC) no 1924/2006			
	What it contains		What it does	
Type of claim:	NCs		HCs	
Name:	Content claims	Comparative claims	Function claims		Reduction of disease risk claims
Parameter:			Based on generally accepted scientific evidence	Based on newly developed scientific data	(includes claims on growth and development of children)
Reference:	Art. 8	Art. 9	Art. 13(1)	Art. 13(5)	Art. 14
Example:	*"Source of vitamin C"*	*"Light" or "Reduced sugar"*	*"Vitamin C increases iron absorption"*	*"Cocoa flavanols help maintain endothelium-dependent vasodilation, which contributes to normal blood flow"*	*"Plant sterols have been shown to lower/reduce blood cholesterol. High cholesterol is a risk factor in the development of coronary heart disease"*

A claim that a food is a source of vitamin C, and any claim likely to have the same meaning for the consumer, may only be made where the product contains at least a significant amount of vitamin C (15% of recommended daily amount = 9mg per 100g or 100ml) (EC, 1990, 2006a, 2006b).

Table 2 is an example of how claims on Vitamin C, and the related conditions of use, appear on the list of permitted Art. 13(1) HCs (EC, 2012).

Table 2: Example of conditions of use for article 13(1) health claims

Nutrient, substance, food or food category	Claim	Conditions of use of the claim
Vitamin C	Vitamin C contributes to the normal function of the immune system	The claim may be used only for food that is at least a significant amount of vitamin C (9 mg per 100 g or 100 ml)
Vitamin C	Vitamin C contributes to maintain the normal function of the immune system during and after intense physical exercise	The claim may be used only for food that provides a daily intake of 200 mg vitamin C. In order to bear the claim, information shall be given to the consumer that the beneficial effect is obtained with a daily intake of 200 mg in addition to the recommended daily intake of vitamin C.
…	…	…

CONCEPTUAL FRAMEWORK

These stricter regulations gave ingredient-manufacturers the opportunity to market their ingredients with clear, well substantiated, HCs, which the food-manufacturers could then use on their final products. With a proprietary and regulated HC, the ingredient-manufacturer could establish their component with a particular claimed beneficial, physiological effect apart from their competitors. These functional ingredients have given rise to numerous, mostly unsuccessful, novel FF concepts (Menrad, 2003). Food manufacturers blatantly marketed their functional products with the same claim that the ingredient manufacturer had used to secure their purchase of the ingredient. The marketing teams seemingly failed to understand that mass market food consumers want to realize quick effects, rather than wait for long-term health effects (Faro, 2010).

So how can manufacturers use NHCs as marketing tools to reach targeted consumers? Which claims should they use? Moreover, how should the claims be phrased within the scope of the legislation? To answer these questions, it is important to understand the basic consumer decision-making process. Before a consumer decides to purchase, he or she has identified an unfulfilled need. To fulfill these needs, consumers will search for information about possible solutions. After evaluating this information, consumers then decide to purchase. This is followed by a post-purchase evaluation that incorporates their experience to ensure a quicker decision process in the future.

To understand this construct better, we analyzed relevant literature on the marketing and consumption of functional food products. Specifically, research on whether consumers *need* FFs, *accept* the functional ingredient, *understand* the benefits of this ingredient, and *trust* NHC on a branded product were reviewed. For the purpose of this discussion, it is most relevant to know how people perceive and understand NHCs. With this, further insights can be gained in how different claim formats play a role in consumer decision-making processes for healthy eating behavior.

Need the product

In a recent article by Wills, et al. (2012), a framework was proposed which outlines the important variables determining FF purchasing behavior. Wennström and Mellentin (2002) discussed similar predictors of successful FFs marketing. Both concur that the food category is an important independent variable affecting the dependent consumer attitude towards a NHC. There is also evidence that HCs and specific nutritional information on product labels can influence the consumer evaluation of the product (Chandon & Wansink, 2011; Kozup, Creyer, & Burton, 2003). For an adequate understanding of NHCs, consumers should categorically *need* the functional product.

The general expectation that healthiness is needed by consumers within their diet was tested in Swedish consumers in 2009. This expectation was tempered by data that shows that Swedish consumers will only justify the use of FFs to improve health when a normal healthy lifestyle is incapable of improving people's health. This complex impression shows that consumers do not place FFs high as a tool to improve their state of health. (Landström, Hursti, & Magnusson, 2009). Another study in Sweden aimed to investigate the actual use of FFs, and whether demographic variables and attitudes to diet and health could predict consumption of FFs. Through a questionnaire (n = 972), Swedish respondents were asked about different aspects of FFs. The results revealed that an astonishing 84% of respondents were familiar with the concept of FF and, of those who had consumed a FF, 25% had perceived a beneficial effect of it. The characteristic Swedish FFs consumer has a high level of education, is health-conscious and interested in healthy foods, and believes in the health effect of FFs (Landström et al., 2007).

It is suspected that presenting information about health can influence the need for the FF. Therefore, it is important to have a good notion on how consumers relate the need for a benefit as specified with a NHC to the need to purchase a FF. This was researched in a conjoint analysis by Hailu, et al. (2009). Through an intercept survey in a shopping mall in Canada consumers were asked to rank attributes of FFs containing probiotics. The relationship between the respondents' characteristics and preferences for product variants was analyzed. Within this study, it was shown that consumers place a strong premium on truly substantiated HCs on FFs.

It can be concluded that, although the consumers prefer to see substantiated claims on FF, not all consumers need FFs. The health functionality of a product is an important driver in the purchasing and consumption behavior of functional products. However, there are other determinants that moderate purchasing behavior, such as consumer acceptance of the ingredient.

Accepted ingredients and/or food types

Theoretically, "functional foods can enable the consumer to lead a healthier life without changing eating habits" (Bech-Larsen & Grunert, 2003). The consumer can embrace this proposition if they *accept* that the functional ingredient is placed within a carrier they know and already consume. If the functional ingredient does not alter the taste or convenience of the carrier, consumers believe they can be healthier without putting extra effort into it.

Therefore, both the type of product and the brand are of utmost importance to the acceptance of an ingredient. This entails that consumers should both accept the functional ingredient and the interaction between the claim and the carrier. For example, most consumers do not accept constipation-related HCs on a soft drink containing a soluble fiber, but might accept the same claim on a functional yogurt-drink.

Among others, Leathwood, et al. (2007) discussed that carrier products have the largest effect on consumers' perception of healthiness and willingness to try the food.

The carrier of a claim can be evaluated using certain characteristics that are listed below. We chose these characteristics because it is suspected that changes in these characteristics have the strongest impact on the perception of NHCs. For the purpose of the research question at hand, FFs, and therefore carriers of claims, are defined by product category, brand, packaging, and location.

Product category
The carrier of a claim always falls within a certain product category. For the purpose of this discussion, FFs can be defined as the investigated product category. However, for consumers it is more relevant to categorize products on the way they appear on their shopping lists (e.g., juice, sports-drink, energy-drink, etc.). This categorization is also used by most supermarket layouts (Bezawada, Balachander, Kannan, & Shankar, 2009).

In all product categories an interesting effect is observed which is coined the "unhealthy equals tasty" intuition (Raghunathan et al., 2006). This intuition describes the effect of health information on taste perception. Generally, consumers tend to think that products that they consider unhealthy are tastier, and products that they consider healthy taste inferior.

Initially, it was often thought by food developers that excellent taste is not a prerequisite for selling functional foods. This thought pattern came from pharmaceutical and OTC preparations experiences which seldom taste well. Users do not care about taste, as long as the medication is functionally sound. To the contrary, the fact that food behaved differently was demonstrated painstakingly after the launch of one of the line of Novartis Aviva functional foods products in 1992. Although the products were clearly substantiated in terms of health, they lacked a good taste and flopped completely. Interestingly, in a study by Tuorila and Cardello (2002), the researchers measured consumer responses after altering the taste of the juice with potassium chloride, a bitter ingredient. The acceptance of taste differences due to a health benefit was investigated. With different levels of off-flavoring and specific HCs, it was shown that the consumption of a functional juice is inversely related to the severity of off-flavor and to the required frequency and duration of consumption. The researchers found no support for the notion that a slight off-flavor is a positive marker of health benefits to consumers. In the other direction, Vidigal, et al. (2010) concluded that, provided that there is sensory pleasure, the information on health benefits can even positively influence sensory acceptance in juices.

Brand
Some, more habitual, loyal, consumers emphasize brands over product categories (e.g., Minute Maid ® or Powerade ®). In Europe the main categories within brands are: *national brands*, *generic brands*, and *low-cost brands* (Clow & Baack, 2004; Keller,

2003). Wennström and Mellentin (2002) imply that, like the product category, well known and trusted brands have a strong influence on the acceptance of a functional ingredient. This influence can be so strong that when a major trusted food brand launches a product with a new ingredient and health benefit, the consumer will trust the product at first sight and purchase it. Additional information on a trusted brand is given further on in the discussion.

Packaging

There has been limited research on the exact role of carrier packaging within NHC perception and the acceptance of functional ingredients in FFs. We suspect that the type of packaging (cans, bottles) has some influence, since cans are mostly used by unhealthy sugar-based sparkling drinks in contrast to bottles or paper. One article (Hawkes, 2010) proposes that the size of the package, and therefore mostly the size of the NHC, plays a significant role in NHC perception. In this light, it is interesting to consider the success of the highly convenient 'one-shot' bottles from Yakult and Danone, which offer a sweetened yogurt-drink with functional ingredients.

More important, the placement of the information on a carrier's package is deemed important for consumer perception. The placement of a NHC on a carrier's package is divided between 'front-of-pack' labeling (FOP) and 'back-of-pack' labeling (BOP). Research shows that FOP is more effective in driving the recall of a NHC (Van Kleef, Van Trijp, Paeps, & Fernández-Celemín, 2008).

Location

The location of the claim on a package is discussed in the section above; however, the location of the carrier might also be relevant on the perception of NHCs. Within this, there are determinant variables such as the place and time where the carrier is encountered. FFs can be purchased in a gas station or in a supermarket, and can be consumed in the morning or in the evening. Surrounding factors, and even the variety of products surrounding the carrier, influence NHC perception (Fernández Celemín & Grunert, 2012).

In conclusion, the carrier strongly determines which ingredients and its related functionality are of benefit to consumers. It should be noted that consumers need to be aware of the existence of the ingredient and be interested in it. These factors are highly influenced by trends within the consumer group. Consumers should both accept the ingredient, as well as accept the benefit. In the development of FFs, manufacturers can achieve this by helping consumers understand the benefit of that ingredient. An alternative is to create 'ingredient trust'. For example, added vitamin C may be sufficient for making a purchase decision irrespective of the reason why it is added because of its widely accepted use.

Understand the benefit

From a public health aspect, it is important that consumers understand which ingredients and foods confer what kind of specific health benefits. Numerous researchers have tried to find better ways to communicate relevant health aspects towards consumers. On the whole, it can be concluded that most consumers only understand health related messages if the right things are communicated to the right people on the right product (K. L. Daniel, Bernhardt, & Eroglu, 2009), advice which undoubtedly needs some further context. In principle, NHCs on FFs should be adapted to their target group and to the specific carrier to ensure adequate understanding. A question that remains is how the claims exactly should be adapted.

In this respect, consumers do not sufficiently process NHCs in real life due to their short exposure. Therefore, some current research data is not coherent with empirical observations. For example, participants in a controlled research setting in which they are instructed to review FFs might understand elaborate claims quite well (i.e.: "plant sterols may inhibit cholesterol absorption. This product contains plant sterols and may therefore helps to maintain cholesterol levels" (J. Y. Kim, Kang, Kwon, & Kim, 2010)). However, in real life situations consumers rarely take the time, and may have insufficient backgrounds, to read and process such difficult sentences.

Furthermore, it is suspected that most consumers often only perceive specific words of some NHCs, and base their understanding from these words. Claims containing negation (e.g.: *not* fattening) can therefore even result in opposite understandings (the product is fattening) (Grant, Malaviya, & Sternthal, 2004). Furthermore, researchers have shown that consumers understand the overall health effects of a product differently even if only one ingredient (contains plant sterol) or one benefit (lowers cholesterol) is mentioned in the claim. This "halo" effect of NHCs may even discourage consumers from seeking further nutrition information (Williams, 2005). Thus to make claims more effective (in terms of actual understanding), longer claims should be adapted to short, and to the point, statements (Wansink, Sonka, & Hasler, 2004).

This notion, however, conflicts with the current strict legal environment. The new European legislation has led to the incorporation of more scientific terms to follow rules on adequate substantiation (EC, 2006a). A balance between substantiation and understandability is preferred. Thus, food manufacturers now have the task to make non-misleading, well-substantiated, understandable claims, a task in which there are certain difficulties. Mariotti et al. (2010) identified six sources of confusion associated with this task.

A first pitfall is the *lexical issue*. The average consumer may find it difficult to understand the scientific terms that the food regulatory authorities prescribe in NHCs. Even though consumers might be familiar with a term (such as metabolism), the exact meaning of the term often remains to be unknown. A good example, in this respect, are the approved article 13(5) claim wordings formulated by the EFSA. As an illustration, we

can take the first ingredient that ever obtained such a HC. The following wording was advised: "FruitFlow ® helps maintain normal platelet aggregation, which contributes to healthy blood flow". Although this claim is fully substantiated, it is not understandable by the average consumer. Broader wording may make the function more comprehensible to these consumers, but often renders the claim to be misleading (Mariotti et al., 2010).

A second pitfall is that HCs could go *beyond scientific truth*. Although the HC "lipids provide energy to the body" is nutritionally correct, consumers might interpret it as "lipids are energizing". The third and fourth pitfalls relate to matching *consumer understanding and reality*. Some consumers confuse between *food and diet* in a way that they tend to think that one product with a HC could balance out another unhealthier product (3). Or that the more they take of a product, the stronger the effect will be (4). Consumer perception should be emphasized when defining a HC wording to avoid misleading the consumer.

The last two hazards for public wellbeing, according to Mariotti et al. (2010), are related to the *interpretation* of HCs. Some consumers might disregard the multifactorial nature of food related illnesses and think that a mere healthy diet is enough to prevent diseases such as cardiovascular disease, diabetes type 2 and cancer (5). Manufacturers should direct the right HCs to the right consumer groups to ensure an adequate effect (6).

From the above, we can conclude that NHCs are often misinterpreted and that the current research methods on NHC understanding might be inadequate. Furthermore, even if the consumers understand the claim, and are not mislead by it, there remains the issue of trusting the claim.

Trust the brand

Previous sections have shown that there are differences in need, acceptance, and understanding of NHCs. The last point on which NHC perception research has focused is developing tools to answer the questions when consumers trust the NHC and the brand that carries the health related claim. In cosmetics, another field of fast moving consumer goods, there have been numerous market failures observed due to untrustworthy pseudo-scientific claims. It is suspected that most consumers did not trust the brand which made the claim (Darke & Ritchie, 2007), an effect that can be generalized to the FFs market.

Foodstuffs fall within the boundaries of the health and life sciences industry, and manufacturers have an important role in marketing disease preventative products (Stremersch, 2008). A content analysis of magazine food advertisements in 1990 through 2008 shows that there was an increase in the use of NCs and HCs. This increase is coined the "medicalization" of food advertising (Zwier, 2009). Often images of the body and mind as malfunctioning, unless remedied by the use of advertised products,

are promoted. Furthermore, this medicalization resulted in lack-of-trust in HCs and food brands (Zwier, 2009).

In the specific case of FFs, the food industry manufacturers have shaped consumers' awareness of these products through these adverts and commercials. However, they have also shaped skepticism and distrust due to the use of low trusted information sources (Bech-Larsen & Scholderer, 2007; Verbeke et al., 2009). The new European regulation concerning HCs tries to make the trust-issue obsolete by establishing a framework for well-substantiated claims.

Svederberg and Wendin (2011) suggest that a minimum of trust is needed for consumers to even use the claim information. Furthermore, their research indicates that HCs are significantly more trusted if manufacturers combine claims with nutrition labeling. Other research shows that consumers who trust the food industry are more likely to buy FFs compared to consumers who do not have trust in the food industry (Siegrist et al., 2008). Thus, it is of importance that trust is restored in health communication towards consumers.

In order to grasp the full understanding of the effect of health claims, the health claim must be seen in its full context, and not in isolation. In addition to the physical context (product category, brand, package, and location and distribution channel) which heavily influence the perception of the health benefit, there are other, maybe even more important, contexts in which the health claim should be studied.

The cultural context, such as the country, ethnic group, subcultures, consumer segments (defined by demographic, socio economic, professional, and psychographic factors) will create different interpretations of the same health claim. Another context is the user centric context. Modern communication models can be defined as user centric. Old models are based on an antiquated idea of sender and receiver. This is a belief that the sender is in control of the communication. However, this is not the case. The receiver is the one who decides to use the information that gratifies and supports his or her belief system.

A last important context is the academic context. This means that HCs are representing the rational communication culture of the academic society who have the tools to decipher and interpret the message in a consistent way across nations and academic groups (in theory). HCs will subsequently be misunderstood and misinterpreted outside this culture.

IMPLICATIONS FOR RESEARCH AND DEVELOPMENT

NHCs appear to provide relevant information for consumers to decide for more healthy choices. However, our research has suggested a backfire effect of labeling foods with some NHCs. The current review examined whether there are common variables which determine functional food purchasing behavior and efficacy expectations. Our

conclusion is that that not all functional foods can be treated equally and that the consumer perception of specific NHCs should be studied in depth. Although the European food industry now has clear guidelines as to how to substantiate health claims (Aggett et al., 2010), there are no guidelines addressing how to properly communicate these health statements. We suggest that the consumer perception of health claims is studied vigorously by both food industry and academia to truly improve consumer health.

In a recent article by Nocella and Kennedy (2012), the urgency to assess consumer understanding of health claims is stressed. In our review, we concur that more research is needed to improve the use and effectiveness of health claims as marketing tools. The European regulations impacted the balance between marketing and R&D efforts in FF development and innovation. We believe that through this regulation, the industry's resources have shifted to proper substantiation of nutrition and health effects of particular foods and ingredients. With this, the parallel increasing costs for the more complex marketing efforts have not been taken into account. Although often seen as a final step in development and innovation, the proper marketing of a functional product is the key to success and should be incorporated early on in the R&D process. In our review, we see that different NHCs, on the same carrier, have a measurable effect on how consumers evaluate the functional efficacy of a food. This is directly attributable to certain characteristics of the claims as well as attributes in the carrier.

Fundamentally, literature indicates that the *type of claim* (NCs, HCs)*, consumer group* (need, acceptance, understanding, trust)*, carrier* (category, brand, packaging, location) and *claim wording* play an important role in consumer perception of FFs, which results in different *functional efficacy expectations* and (*re)purchase intent*.

To increase the understanding and attitude towards NHCs, future consumer studies should look much more to the relation between the understudied determinants such as body mass index, personal and cultural beliefs, sensory attributes, wording, and nutrition knowledge. Furthermore, available studies that investigate consumer perceptions across a wide range of different health benefits and claim types are highly limited, indicating a need for more research. This, and the greatly varying methodologies described in the available publications, make it hard to compare results between existing research on the correct use of NHC as marketing tools. We also believe that all future research should focus on obtaining actual consumer behavior data, rather than self-reported preferences to ensure reliable and comparable data. NHC perception should be studied on a subconscious level to minimize confounding effects. One important limitation of consciously measuring decision processes is that it significantly changes behavior (Morwitz, Johnson, & Schmittlein, 1993).

This detailed analysis of determinants of NHC perception is a helpful tool in understanding the more general implications of correctly communicating nutrition and health benefits on foods and beverages. The research fits in the interdisciplinairy approach which is used in finding solutions for the detrimental effects of an

unwholesome diet on health. Moreover, it provides a benefit to companies who want to understand how to make consumer communication more effective. This could also benefit public policy makers, as they better understand how to design the health claims system to achieve the edesired effect on consumer choices.

Although from a public health standpoint, one could argue that claims, which have been approved and authorized, are mostly only well-established nutrient function claims. These may stimulate the addition of nutrients to fortified foods rather than true functional foods leaving the regulation to stifle true innovation. Only time will tell.

Chapter 3

Misconceptions about fructose-containing sugars and their role in the obesity epidemic

ABSTRACT

A causal role of fructose intake in the etiology of the global obesity epidemic has been proposed in recent years. This proposition, however, rests on controversial interpretations of two distinct lines of research. On one hand, in mechanistic intervention studies, detrimental metabolic effects have been observed after excessive isolated fructose intakes in animals and human subjects. On the other hand, food disappearance data indicate that fructose consumption from added sugars has increased over the past decades and paralleled the increase in obesity. Both lines of research are presently insufficient to demonstrate a causal role of fructose in metabolic diseases, however. Most mechanistic intervention studies were performed on subjects fed large amounts of pure fructose, while fructose is ordinarily ingested together with glucose. The use of food disappearance data does not accurately reflect food consumption, and hence cannot be used as evidence of a causal link between fructose intake and obesity. Based on a thorough review of the literature, we demonstrate that fructose, as commonly consumed in mixed carbohydrate sources, does not exert specific metabolic effects that can account for an increase in body weight. Consequently, public health recommendations and policies aiming at reducing fructose consumption only, without additional diet and lifestyle targets, would be disputable and impractical. Although the available evidence indicates that the consumption of sugar-sweetened beverages is associated with body-weight gain, and it may be that fructose is among the main constituents of these beverages, energy overconsumption is much more important to consider in terms of the obesity epidemic.

INTRODUCTION

Several studies and reports have indicated an increased consumption of sugar sweetened beverages (SSBs) over the period 1970-2005 in the U.S. and Europe (Bleich, Wang, Wang, & Gortmaker, 2009; Duffey & Popkin, 2012; Euromonitor, 2011; Nielsen & Popkin, 2004; Popkin & Nielsen, 2012; Storey, Forshee, & Anderson, 2006; Y. C. Wang, Gortmaker, Sobol, & Kuntz, 2006). The SSB category includes sodas (soft drinks), fruit drinks, sports drinks, ready-to-drink sweetened tea and coffee, rice drinks, bean beverages, sugared milk drinks, sugar cane beverages and non-alcoholic wines or malt beverages. The increased intake was related to a high availability of such products in the market, amplified marketing efforts, and larger portion sizes, which increased three- to five-fold over time (Young & Nestle, 2003). As such, SSB consumption was suggested to be a considerable amount of total daily energy intake (Y. C. Wang, Bleich, & Gortmaker, 2008).

Interestingly, over the last five years, the global annual consumption of carbonated soft drinks has remained constant or even has declined (Welsh, Sharma, Grellinger, et al., 2011), while bottled water has increased to more than one liter per person per year in the last years (Euromonitor, 2013a). Obesity rates, however, seem to have increased independent of these shifts in beverage intake (Ogden, Carroll, Kit, & Flegal, 2012). An overview of the average Western European consumption of the five most common drink categories, including SSBs, per capita per year are given in Table 3 below (Euromonitor, 2013b). The U.S. data are given in Table 4 (Euromonitor, 2013b). Note that in the U.S., carbonated water is replaced by sports drinks in the five most consumed categories.

Table 3: Average Western European consumption of five most common drink categories, including SSBs, in liters per person per year (Euromonitor, 2013b)

Drink category:	European average yearly consumption (in liters per person)					
	2007:	2008:	2009:	2010:	2011:	2012:
Still bottled water	54.0	55.2	55.6	56.3	57.5	58.5
Cola carbonates	28.4	28.7	29.4	30.1	30.7	31.0
Carbonated bottled water	28.2	27.4	27.2	27.1	27.4	27.7
Non-cola carbonates	20.7	20.6	20.8	20.9	20.9	20.9
100% juice	12.9	12.5	12.1	11.9	11.5	11.2

Table 4: Average U.S. consumption of five most common drink categories, including SSBs, in liters per person per year (Euromonitor, 2013b)

Drink category:	U.S. yearly average consumption (in liters per person)					
	2007:	2008:	2009:	2010:	2011:	2012:
Still bottled water	70.3	68.0	66.5	66.2	68.2	70.9
Cola carbonates	71.5	67.9	65.0	62.8	59.5	56.5
Non-cola carbonates	56.1	54.9	54.0	54.9	55.7	55.9
Sports Drinks	16.3	15.4	13.9	14.8	17.0	17.3
100% juice	16.5	16.4	16.4	15.6	14.8	14.3

Although data from Table 3 and Table 4 were obtained through trade sources and national statistics (by Euromonitor International), which did not account for wastage and were not corrected for export to other countries, it can be concluded that, even if intake patterns are shifting, consumers in different parts of the world still purchase a relatively high amount of SSBs.

In this light, the systematic reviews by Malik et al. (2006) in 2006 and Hu and Malik (2010) concluded that such quantitative SSB consumption were associated with both weight gain and type 2 diabetes prevalence. Moreover, results from a survey in Australia indicated that high SSB intake may be an important predictor of cardiometabolic risk (Ambrosini et al., 2013). A scientific opinion by the European Food Safety Authority (EFSA), however, concluded that additional justification for the correlation between SSB consumption and such adverse health effects was required (Agostoni et al., 2010).

In this respect, one may question what in SSBs could be responsible for these adverse effects on health (Kaiser, Shikany, Keating, & Allison, 2013). More specifically, a) is there evidence that specific sugars, such as fructose and glucose, as present in sucrose and high-fructose corn syrup (HFCS), promote excess energy intake, and b) is there evidence that excess energy intake as sugars is more detrimental to health than excess energy as fat, or as complex carbohydrate present in potatoes, rice, refined cereals, and so forth (Ervin & Ogden, 2013).

Since the recent publications of Lustig et al. (Lustig, 2010; Lustig, Schmidt, & Brindis, 2012), in which it was suggested that fructose is toxic and should be "treated as alcohol", the daily news all over the world highlighted fructose in SSBs as a potential poison. It was proposed that fructose is a causal factor in obesity etiology, based on the scientific evidence that substantiated that fructose, when consumed in excessive amounts, led to detrimental effects on body weight regulation, lipid metabolism and glucose homeostasis in animals and in humans (R.J. Johnson, Lanaspa, & Sanchez-lozada, 2012; Melanson et al., 2008; Perez-Pozo et al., 2009; Rizkalla, 2010). As a result, an overall reduction in the global consumption of fructose-containing sugars was recommended in recent literature (Bleich et al., 2009; G.A. Bray, 2008; George A Bray, 2012, 2013; George A Bray, Nielsen, & Popkin, 2004; C. Brown, Dulloo, & Montani,

2008; I. J. Brown et al., 2011; Vasanti S Malik & Hu, 2012; Vasanti S Malik et al., 2006; Popkin, 2012; Popkin & Nielsen, 2012). To achieve this reduction, various measures have been proposed (D. M. Klurfeld, 2013). Most of which related to extra taxes on foods, such as SSBs, that are considered unhealthy because of their high fructose content (Caprio, 2012; Chaufan, Hong, & Fox, 2009; Cohen & Babey, 2012; Elbel, Cantor, & Mijanovich, 2012; Pomeranz & Brownell, 2012; Popkin & Nielsen, 2012). However, raising tax levels, and consequently purchase prices, has generally failed to change consumption behaviors (D. R. Just & Payne, 2009). In line with this, also the removal of products from the site of availability has been discussed as possibly inappropriate in changing purchase behavior, since it may result in exchanging the purchase with similar products (Wansink et al., 2012). In the field studies of Wansink et al. (2012), it was evidenced that taxing soft drinks in Utica, New York, led beer-buying households to increase their purchases of beer. Similarly, taking out snacks and soft drinks from vending machines did not withhold children from buying such products at other locations or finding other alternatives that are also high in sugars, fat, and energy-dense.

Moreover, as the human body does not differentiate fructose absorption, whether it comes from high-fructose corn syrup, cane or beet sugar, or from an intrinsic source such as that present in fruits or fruit juices (Agostoni et al., 2010; Lê & Tappy, 2006; White, 2008), would this reduction also be necessary for fruits that contain relatively large amounts of fructose such as apples, apricots and ripe bananas? Should honey also be removed from our diet (Bogdanov, Jurendic, Sieber, & Gallmann, 2008)? These questions have confused the typical consumer of sweet (and sweetened) food products (Casazza et al., 2013). This confusion may have been intensified by the issuing of a scientific opinion on fructose by EFSA in 2011. With this, European food manufactures can claim that "Consumption of fructose leads to a lower blood glucose rise than consumption of sucrose or glucose" (Agostoni et al., 2011, p. p. 7). Having evaluated the scientific literature at their disposal (Bantle et al., 1983; Crapo, Kolterman, & Olefsky, 1980; Lê & Tappy, 2006; Stanhope & Havel, 2008, 2010; Stanhope et al., 2009; Tappy & Lê, 2010; Vasankari & Vasankari, 2006), the EFSA panel assumed that, when fructose replaces sucrose or glucose in foods or beverages, the claimed effect will be obtained. The panel took into account two human intervention studies (Bantle et al., 1983; Crapo et al., 1980), which showed a consistent significant reduction in postprandial glycemic responses. This occurred without disproportionally increasing postprandial insulinemic responses. Further, the panel noted that the mechanism by which fructose (when replacing sucrose or glucose) in food or beverages could exert the claimed effect was well established.

The panel did note that high intakes of fructose (set at ≥25 % of total energy) was shown to lead to metabolic complications such as dyslipidemia, insulin resistance and increased visceral adiposity, based on several review articles (Lê & Tappy, 2006; Stanhope & Havel, 2008, 2010; Stanhope et al., 2009; Tappy & Lê, 2010). With this

scientific opinion, and related health claim, the panel clearly took a different position than the opinion that fructose is toxic and should be treated as alcohol.

So, what is the current status concerning the role of fructose-containing sugar sweetened beverages that supply glucose along with fructose? Identifying added fructose as a prime cause of obesity can be misleading to the public, as well as policy makers, about the "truth of obesity" in the case that causality remains unproven. Obesity is recognized to be a multiple-factor-related health problem (Grundy, 1998), in which lifestyle factors (Martinez-Gonzalez, Alfredo Martinez, Hu, Gibney, & Kearney, 1999), eating behavior (Torres & Nowson, 2007) and socio-economical aspects (Sobal & Stunkard, 1989) all play a key role, and fructose intake may be just one among several factors involved in its prevalence. At present, there are reasons to believe that isolated reductions in added fructose-containing sugar intake, as recently investigated (de Ruyter, Olthof, Seidell, & Katan, 2012; Ebbeling et al., 2012), will not lead to a decrease in obesity prevalence. When similar isolated reductions were undertaken concerning added fats (Golay & Bobbioni, 1997), the desired overall reduction in fat intake and development of low fat/light products were not observed (Allais, Bertail, & Nichèle, 2010).

Fructose is considered by some authors as a significant culprit for obesity and related disorders based on three categories of arguments:

(1) Arguments that generalize data derived from animal models of obesity (in which sugar overfeeding was used as an experimental tool to increase body weight) as well as human studies in which excessive fructose intakes were used to study the mechanisms of metabolic dysregulation.

(2) Arguments that confuse the relative contents of glucose and fructose in industrially produced food and beverages.

(3) Arguments that underestimate our personal responsibility to remain physically active and to consume a healthy diet.

A plethora of unbalanced reviews on the topic have recently been published (Gaby, 2005; Lustig, 2010; K. Parker, Salas, & Nwosu, 2010), including citations to other reviews instead of addressing the authentic data. In the present review, we therefore look at evidence regarding both positive and negative effects of fructose and fructose-containing sugar sources on obesity, as described in recent peer-reviewed research papers.

METABOLIC EFFECTS OF FRUCTOSE

In order to study the effects of fructose on metabolism, scientists have generally used dosages high enough to observe some significant effects, mostly in animal studies and sometimes in human intervention research. Based on recent publications (Hallfrisch, 1990; Havel, 2008; Rizkalla, 2010; Tappy & Lê, 2010), we summarize a number of key findings from studies with high to excessive fructose intakes. It is important to note that fructose intake varies between individuals, based on their daily consumption patterns (Vos, Kimmons, Gillespie, Welsh, & Blanck, 2008). Through a 2008 U.S. survey in 21,483 children and adults, it was found that the mean intake of fructose was 9.7% (SED: 0.1) of total energy intake, and that 95% of these sampled individuals consumed less than 19.5% (SED: 0.7) of fructose as part of their total energy intake (Vos et al., 2008). Therefore, in the discussion below, we assume fructose intake as excessive as its pure intake amount is larger than 20% of daily energy.

Effects of excessive doses of fructose

Already in 1993, researchers (Mayes, 1993) agreed that excessive fructose consumption (then defined as 7.5% to 70% of total energy intake) induces immediate *de novo* lipogenesis in both animals and humans, because, in different experimental settings, it circumvented substrate inhibition feedback mechanisms that are present for glucose when it enters glycolysis. It was shown that the dietary fructose fraction not converted to lactate in the intestinal epithelium was rapidly taken up by the liver, where it was subsequently converted first into fructose-1-phosphate, and then to triose-phosphate and pyruvate/lactate. These are both potential substrates for liver glycogen synthesis and for fatty acid production, leading to an increased triacylglycerol (TAG) release from the liver into blood. Also, it was found that fructose stimulated key lipogenic enzymes by activating sterol-regulatory-element-binding protein-1c (SREBP-1c) in the livers of mice (Shimomura et al., 2000).

In addition, it was found that high fructose loads (50% of total diet) led to an increase in peroxisome proliferator-activated receptor gamma co-activator 1α and 1β (PGC-1α and PGC-1β) which promoted insulin resistance and lipogenesis (Havel, 1997; Rizkalla et al., 1992), as well as decreased insulin receptor activation and insulin receptor substrate phosphorylation (Puigserver & Spiegelman, 2003). Subsequently, lipogenesis induced by this high fructose load was associated with the formation of larger fat deposits in adipose tissue and muscle, in animal models (Havel, 1997; Rizkalla et al., 1992). However, to the best of our knowledge, there are no results of long-term human intervention studies available in which comparable quantities of fructose were investigated. One short term intervention study (96 hours) examined the effects of 50% excess energy as fructose, sucrose, or glucose, indicated that, even under these drastic

conditions, *de novo* lipogenesis remained a minor pathway for fructose disposal in both lean and obese women (McDevitt et al., 2001).

Hyperuricemia may occur as a consequence of rapid fructose entry from portal blood into the liver, where fructose will reduce the total adenosine nucleotide (TAN) pool in liver cells. A degradation of hepatic TAN will result in production of uric acid. In a within-subjects intervention, this was measured in obese men and women where pure fructose intake provided 30% of total energy-intake (Teff et al., 2009). Chronic hyperuricemia was also proposed to act as a promoter of insulin resistance and diabetes type 2 development (Vuorinen-Markkola & Yki-Järvinen, 1994). Based on recent findings from *in vivo* research in fructose-fed rats, it was suggested that uric acid may impair insulin's action by decreasing insulin-mediated muscle vasodilatation (Nakagawa et al., 2006). In addition, it may possibly act as an intracellular mediator to enhance hepatic *de novo* lipogenesis (Lanaspa et al., 2012). It remains unclear if these metabolic consequences can occur in humans considering moderate fructose intake level and complex dietary composition. We will discuss this in detail below.

In older adults consuming fructose daily through SSBs, fructose led to stressful conditions in hepatocytes (Abdelmalek et al., 2010) resulting in the release of tumor necrosis factor-α (TNF-α), a strong pro-inflammatory messenger involved in insulin resistance development (Togashi, Ura, Higashiura, Murakami, & Shimamoto, 2000). Also in rats, excessive fructose intake (>62% of total energy) induced oxidative stress, mitochondrial and endothelial dysfunction, resulting in hypertension (Bezerra et al., 2000).

In summary, it appears that excessive fructose intake can have deleterious metabolic effects in both animals and humans.

Disputable interpretations

In contrast to these deleterious effects observed in animal models and in human trials with excessive intakes, the metabolic effects of fructose presented in ordinary human diets remain poorly investigated and highly controversial. The assumption that fructose was directly involved in the obesity occurrence was relied on correlation data between increase of HFCS consumption and obesity prevalence in the U.S. This assumption has been considered as misleading for several reasons.

At the first, the correlation of HFCS and obesity data only happened in North America. In Europe, there was also an increase in obesity prevalence during the same period, but HFCS was not consumed to any significant amount. Moreover, the term high-FRUCTOSE corn syrup often led people to believe that it had a very high fructose content. In fact, the relative proportion of fructose to glucose in HFCS 55 (55% fructose; used in most soft drinks) and HFCS 42 (42% fructose; mostly used in non-beverage applications) is not that different from sucrose (50%-50%) (White, 2008), although absolute levels as analyzed in drinks may vary. In this respect, free fructose content in

sucrose sweetened acid-containing beverages, such as colas, was found to be increased during storage due to acid-induced sucrose hydrolysis (Babsky, Toribio, & Lozano, 1986; Ventura, Davis, & Goran, 2010).

A prospective cohort study (Fung et al., 2009) indicated that higher consumption of SSBs was associated with a higher risk of coronary heart disease. Additionally, a cross-sectional study (I. J. Brown et al., 2011) and two other cohort studies (Chen et al., 2010; Dhingra et al., 2007) positively associated a reduction in SSB consumption with a reduction of disease risk factors such as elevated blood pressure or weight gain. It should be mentioned, however, that relevant intervention studies with such risk factors as end-point are lacking. Interestingly, four large cohort studies showed no relation between moderate sugar intake and type 2 diabetes (Abdelmalek et al., 2012; Janket, Manson, Sesso, Buring, & Liu, 2003; Meyer et al., 2000; Paynter et al., 2006). The question of whether the aforementioned effects are really caused by fructose can therefore not be answered by the observational data since these show associations, not causality.

In this respect, it is important to note that through analysis of the same set of data, a positive association between obesity risk and SSB intakes was found without adjustment for total energy intake (Forshee, Anderson, & Storey, 2008). These outcomes from the modelling analyses may indicate that SSB consumption was not associated with obesity risk if potential impact of total energy intake was accounted for. In this light, a meta-analysis (Forshee et al., 2008), a descriptive time series study (Duffey & Popkin, 2008), and a cohort study (de Koning, Malik, Rimm, Willett, & Hu, 2011) did report a relationship between sugar intake or SSB intake and diabetes, dyslipidemia, and cardiometabolic risk factors. In all these studies, however, the relationship disappeared when analysis was adjusted for body weight, strongly suggesting that obesity rather than sugar intake may be the associated factor with the disease status or biomarkers mentioned.

Goran, Ulijaszek, and Ventura (2012) did find that diabetes prevalence was 20 percent higher in EU countries with higher availability of HFCS, as compared to countries with low availability. The authors stated that these differences were retained after adjusting for country-level estimates of body mass index (BMI), population, and gross domestic product. An analysis of the study, however, shed an interesting light on the reliability of these findings. The cited HFCS consumption data for the EU countries were, in fact, not consumption data at all but rather production data. In the EU, HFCS travels freely across EU borders and can thus be consumed anywhere. For instance, the article stressed that Hungary consumed significant amounts of HFCS and also showed a higher prevalence of diabetes (Kmietowicz, 2012). In reality, most HFCS from Hungary, which was one of Europe's leading producers of this ingredient, has been exported (CMO, 2012). Consumption and production figures are, as such, two entirely different things. The lack of adequate consumption data often results in the usage of production data. However, even if export and import figures were accounted for, food spoilage

(which can be up to 30% (Gustavsson, Cederberg, Sonesson, Van Otterdijk, & Meybeck, 2011)) seriously impedes on the above findings as is also the case in many other epidemiological research papers that have used sugar production or disappearance data as the bases for correlations with obesity, as well as papers that cite such data for building their arguments. More recently, Basu, Yoffe, Hills, and Lustig (2013) used the United Nations Food and Agricultural Organization food supply data to capture the market availability of different food items worldwide. From this, the authors concluded that an increase in sugar availability was associated with higher diabetes prevalence after testing for potential selection biases and controlling for other food types, total energy-intake, overweight and obesity, period-effects, and several socioeconomic variables such as aging, urbanization, and income. As discussed, the market availability of food is a debatable indicator for sugar consumption.

In this respect, a recent New York Times article (Strom, 2012) pointed out that, due to incorrect methodology, as per discussed by Muth et al. (2011), the U.S. sugar consumption in recent years was overestimated by >20%. Interestingly, the author implied that the sugar consumption has not risen substantially since the '80s. This makes many assumptions based on higher production/per capita consumption data unsubstantiated. In addition, data obtained from the U.S. National Health and Nutrition Examination Surveys, in 2005-2010 (Ervin & Ogden, 2013) concluded that total calories from added sugars remained rather constant, or even declined in some segments, in recent years. Moreover, the consumption of added sugar through beverages contributed to only 1/3 of total added sugar intake, indicating that the energy from added sugars mostly came from foods rather than beverages.

Alternative and balancing views

In animal models, excessive fructose diets led to hyperphagia, obesity, and the development of a metabolic syndrome (Rizkalla, 2010). In humans, however, evidence is scarce. Short-term studies that used large amounts of fructose have led to relatively modest changes in metabolic profile (including hypertriglyceridemia) and a moderate decrease in hepatic insulin sensitivity and no change in whole body/muscle insulin resistance (Faeh et al., 2005; Lê et al., 2009; Lê & Tappy, 2006). This may suggest that there is a large metabolic plasticity in response to dietary changes and what we observe are minor adjustments of metabolic pathways rather than pathogenic events.

There has been no evidence about that relatively large amount SSB consumption could be associated with obesity, diabetes, or cardiometabolic risk in professional athletes who usually consumed SSB as energy and dehydration drinks. On the other hand, there was evidence that physical inactivity, even within a few days, causes insulin resistance and dyslipidemia in normal healthy individuals (Hamburg et al., 2007). In this regard, two randomized within-subjects studies in healthy males and females showed that higher plasma triacylglycerol, induced by a high carbohydrate diet, were

completely prevented by physical activity (Egli et al., 2013; Koutsari, Karpe, Humphreys, Frayn, & Hardman, 2001). Thus, the metabolic consequences of a high mixed glucose-fructose intake can be significantly modulated by exercise. In a narrative review (Elliott, Keim, Stern, Teff, & Havel, 2002), it was reported that high fructose consumption induced insulin resistance, impaired glucose tolerance, hyperinsulinemia, hypertriglyceridemia and hypertension in animal models. The data in humans, however, were considered less clear. In this respect, fructose consumption, even in large amounts (17% of total energy), did not result in significant effects in healthy males but did cause these effects in healthy women (Bantle, Raatz, Thomas, & Georgopoulos, 2000). Moreover, such fructose consumption did not stimulate *de novo* lipogenesis in premenopausal women (Couchepin et al., 2008; Tran et al., 2010). In a review addressing sugars, insulin sensitivity, and the postprandial state (Daly, 2003), it was concluded that research on animals, particularly rodents, has shown a clear and consistent effect of high-sucrose and high-fructose diets in decreasing insulin sensitivity. Again, it was underlined that experiments in humans have produced very conflicting results, as there is only limited evidence from human consumption data, using fructose levels of higher than 15% of daily energy intake, for such an effect on insulin sensitivity.

If it is not fructose, is it just added sugars in a solution?

The suggestion that HFCS is causal to obesity (George A Bray et al., 2004; Lakhan & Kirchgessner, 2013) cannot explain why overweight and diabetes have also increased over the past decades in regions where HFCS is not (or hardly being) used in soft drinks (e.g.: Europe and India), or where SSB consumption is limited (Asia, Africa) (D. Klurfeld, Foreyt, Angelopoulos, & Rippe, 2013).

   Several reviews and position papers have proposed that SSBs are causally related to obesity because energy-containing liquids did not elicited the same satiety signals as energy-containing solid foods (DiMeglio & Mattes, 2000; Hu & Malik, 2010; Mærsk et al., 2012; Melanson et al., 2007; Soenen & Westerterp-Plantenga, 2007). This hypothesis was partially supported by studies that showed that supplementation with SSBs increased body weight, and thus that the intake of energy from other sources was not adequately suppressed (de Ruyter et al., 2012; Ebbeling et al., 2012). In such studies, however, the cumulated weight gain observed was substantially lower than expected from added SSB energy, indicating that there was at least partial compensation (Mærsk et al., 2012; Reid, Hammersley, Duffy, & Ballantyne). This compensatory effect, among other problems in this research area, were highlighted recently by Allison (2013) and quantified by Kaiser et al. (2013). In their meta-analysis (Kaiser et al., 2013), the observed weight gain from six randomized controlled trials in which the effect of SSBs on weight gain were tested was compared to the theoretical weight gain in these studies. It was found that the observed data were, on average, 85% lower than the theoretical weight gain indicating a high compensation effect. In other

words, the effect of added sugars on weight gain was much smaller than the theoretically assumed result. This does not mean that a frequent consumption of SSB does not impact on weight gain. It does show, however, that other factors do contribute significantly as well.

In a recent cross-sectional study, it was reported that U.S. adolescents, who consumed high amounts of added sugars (20-30% of total energy), had higher blood cholesterol and triacylglycerol compared to low sugar consumers (10-20% of total energy) (Welsh, Sharma, Cunningham, & Vos, 2011). High sugar consumers had similar body weight and total energy intake compared to low sugar consumers, but a lower intake of energy from fat and protein, indicating that sugar intake was at least partially compensated (Welsh, Sharma, Cunningham, et al., 2011). Several smaller studies (Judith Rodin, 1990; J Rodin, Reed, & Jamner, 1988) documented that liquid sugar pre-loads significantly reduced spontaneous food intake at subsequent buffet meals and that fructose was as efficient as glucose – in some instances even more efficient – in this regard.

Thus, this point of view further substantiates the weakness in making this case since all energy-containing beverages seem to have similar effects (Te Morenga, Mallard, & Mann, 2013), leading Moran (2009) to conclude that results have been inconsistent and that particular findings concerning the effects of fructose on satiety appear to depend on the timing, eating context, and volume of preload relative to the test meal. Another study (Sievenpiper, de Souza, & Jenkins, 2012) listed the effect of fructose on body weight in controlled feeding trials. Herein, the authors concluded that fructose does not seem to cause weight gain when it is substituted for other carbohydrates in diets providing similar energy content. In this respect, the question arises whether consuming energy through beverages results in fewer satiety signals compared to energy from solid foods. To answer this, the U.S. 2010 Dietary Guidelines Advisory Committee (Slavin, 2012) reviewed the literatures and concluded: "A limited body of evidence shows conflicting results about whether liquid and solid foods differ in their effects on energy intake and body weight, except that liquids in the form of soup may lead to decreased energy intake and body weight".

Most recently, Page et al. (2013) performed a study on neurophysiologic factors that might underlie associations between fructose consumption and weight gain. For this purpose, 20 healthy adult volunteers underwent two MRI sessions at Yale University in conjunction with fructose- glucose drink ingestion in a blinded, random-order, crossover design. The authors concluded that glucose but not fructose ingestion reduced the activation of the hypothalamus, insula, and striatum – brain regions that regulate appetite, motivation, and reward processing. Glucose ingestion also increased functional connections between the hypothalamic-striatal network and increased satiety. The disparate responses to fructose were associated with lower systemic levels of the satiety-signaling hormone insulin and were not likely attributable to an inability of fructose to cross the blood-brain barrier into the hypothalamus, or to a lack of

hypothalamic expression of genes necessary for fructose metabolism. The authors discussed a number of limitations of this well designed study, but did not consider the possibility that the observed effects were merely mediated by hyperinsulinemia present after glucose, but not after fructose, ingestion. They also did not discuss that, in real life, fructose is never consumed as a single carbohydrate source but always together with glucose. Thus, dietary intakes of sucrose and HFCS, all raise insulin level significantly, and should not induce the observed brain responses to feeding fructose alone.

FRUCTOSE AND OBESITY

As discussed, it is generally believed that the consumption of fructose leads to an immediate increase in lipid synthesis in the liver and subsequent increase in circulating TAGs. This assumed relation between fructose, lipid synthesis and hypertriglyceridemia has been extrapolated to obesity (G.A. Bray, 2008; George A Bray et al., 2004). However, careful studies in humans, using stable isotopes, do not confirm this relation. Chong, Fielding, and Frayn (2007) observed that, after a load of 0.75 g fructose per kg body weight, the enhanced postprandial elevation of plasma TAG is mainly explained by a small impact of fructose on insulin compared to glucose, reducing the TAG clearance, rather than as a result of new synthesized lipids which appeared to be small. Given the fact that about 50% of a fructose load is converted into glucose, 25% into lactate, and approximately 15% into glycogen, *de novo* lipogenesis is a minor pathway for fructose disposal (Tappy & Lê, 2010). This is in line with the substantial evidence reviewed by Hellerstein, Schwarz, and Neese (1996), who summarized the evidence as follows:

- After consumption of a normal diet, < 3% of post-absorptive VLDL was estimated to come from sugar;
- In the fed state, < 5-7% of VLDL post-absorptive comes from sugar;
- When given 250 g of fructose within 6 hrs, <10% of fructose load was converted to lipids, equivalent to < 1g/hr in absolute amounts;
- Daily overfeeding with 150-200 g fat and 750-1000 g carbohydrates led to a *de novo* synthesis of 5 g fat/day, equivalent to < 3% of the total fat consumed.

Accordingly, Hellerstein et al. (1996) concluded that *de novo* net lipogenesis, after fructose or sugar consumption, is in fact very small. The explanation for these observations is that the consumed carbohydrates are primarily cleared from the blood, to be oxidized in energy metabolism and/or stored as glycogen, at the expense of fat oxidation, which drops due to lipolysis inhibition by insulin and reduced NEFA availability. Thus, only very small amounts of lipids are synthesized after large fructose/sugar/CHO loads, unless extreme carbohydrate overloading is sustained for several days (Acheson et al., 1988).

Very recently, Sun and Empie (2012) reviewed isotopic tracer studies in humans. The authors summarized their findings as follows: "Fructose is readily absorbed and its absorption is facilitated by the presence of co-ingested glucose. Sucrose, honey, 50:50 glucose-fructose mixtures and HFCS all appear to be similarly absorbed. Fructose itself is retained by the liver, while glucose is mainly released into the circulation and utilized peripherally. Plasma levels of fructose are an order of magnitude (10– 50 folds) lower than circulating glucose, and fructose elicits only a modest insulin response". Further, the authors stated that the average oxidation rate of fructose was similar in non-exercising and exercising conditions (45.0% and 48.8%, respectively). Moreover, they underscored that when fructose is ingested together with glucose, the mean oxidation rate of the mixed sugars increased significantly.

In their review, the authors described the metabolic fate of pure fructose based on several studies (Sun & Empie, 2012). Following 3-6 hours after ingestion, on average 41% (SD: 10.5) fructose was converted to glucose. Only a small percentage of ingested fructose (<1%) was directly converted to plasma TAG. Approximately a quarter of ingested fructose was converted into lactate within a few hours. The authors discussed further that the observed increases in plasma TAG and *de novo* lipogenesis, as observed in various studies, can arise from both increased lipid synthesis and decreased lipid clearance, and that the relative contributions were not addressed in any detail in the available studies. Furthermore, the fate of fructose ingested together with glucose had received little attention so far. In addition, habitual fructose intake, health status (and more specifically insulin resistance), gender, or ethnic/genetic background were all important factors which may modulate sugar-lipid relationships but had not yet been adequately investigated.

Accordingly, the influence of fructose consumption on plasma lipids and *de novo* lipogenesis remains controversial and understudied and conclusions that fructose is a liver toxin similar to alcohol are certainly premature.

Fructose, uric acid and insulin resistance

In 2009, (Richard J Johnson et al.) hypothesized that excessive fructose intake (>50 g/d) may be one of the underlying etiologies of metabolic syndrome and type 2 diabetes. The authors suggest that this occurs through mechanisms by which rapidly increased fructose phosphorylation in liver cells results in total adenine nucleotide degradation leading to the liberation of elevated uric acid, leading to higher cardiovascular risk (Feig, Kang, & Johnson, 2008). In the work by Sánchez-Lozada et al. (2010), rats were fed either a combination of 30% fructose and 30% glucose or 60% sucrose, while control rats were fed normal rat chow containing 60% corn starch. Diets containing 30% of either both free fructose and free glucose, or as the disaccharide sucrose, induced metabolic syndrome, intra-hepatic accumulation of uric acid and triacylglycerol, leading

to fatty liver. Relevant for the interpretation of this work is that the level of fructose consumed by the rats was excessive and does not reflect levels consumed by humans.

Another work, by Abdelmalek et al. (2012), investigated 25 diabetic adults receiving an intravenous fructose challenge. Based on their data, the authors concluded that high-fructose consumption depletes hepatic ATP and impairs recovery from ATP depletion after an intravenous fructose challenge. This approach, however, relied on the intravenous administration of > 25 grams of pure fructose (250 mg/kg body weight) within one minute, resulting in a massive hepatic disposal. Similar ATP depletion has also been observed with large oral fructose load, but led to only small increases in uric acid concentrations in healthy subjects (Oberhaensli et al., 1987). However, it has been recently reported that ingestion of even larger amounts of fructose failed to acutely increase uric acid concentration when ingested in split doses throughout several days, suggesting that liver ATP depletion is unlikely to occur with usual patterns of sugar consumption (Lecoultre et al., 2013).

Lin et al. (2012) also observed that fructose consumption resulted in higher serum uric acid levels in individuals with a BMI of >30. Interestingly, their study showed that there was no effect of fructose intake in the subjects with a BMI between 25 and 29, although serum uric acid showed a trend to be elevated depending on body weight status. Moreover, the blood samples were drawn after an overnight fast in the morning, ruling out any postprandial effect of fructose ingestion. Accordingly, the effect on serum uric acid was more likely to be secondary to obesity-metabolic syndrome than to fructose consumption per se. In this study, intake was calculated from food frequency recall, which are known to have a low level of accuracy (Dodd et al., 2006). Moreover, food frequency intake data are based on food composition tables that are not controlled for recipe related changes of food and beverage products on the market. This double chance of error should not be neglected.

Limited data are available on serum uric acid changes after realistic dietary loads of fructose-containing sugars (Angelopoulos et al., 2009). For example, Akhavan and Anderson (2007) tested solutions containing different ratios of glucose and fructose. In their work, overnight fasted men received a standardized breakfast in the morning. Four hours later, a 300 Kcal (1.26 MJ) drink was ingested within 3 minutes. The solutions were sweetened with either high-fructose corn syrup containing 55% of fructose, sucrose or the monosaccharide forms of glucose and fructose in specific ratios as follows: 80% glucose/20% fructose (G80/F20), sucrose, G50/F50, G35/F65, and G20/F80. At 75 minutes, uric acid concentrations were highest after G20/F80. The sucrose and F50/G50 solutions each resulted in significant lower uric acid concentrations than did the G20:F80 solution, but they did not differ significantly from any other solutions. Uric acid areas under the curve (AUC) did not differ significantly after the G35:F65, G50:G50, and sucrose solutions. In other research (Buemann et al., 2000), only a weak response of serum uric acid to fructose was found.

Very recently, D. D. Wang et al. (2012) conducted a systematic review and meta-analysis of controlled fructose feeding trials. The authors noted that hyperenergetic supplementation of control diets with excessive fructose (+35% excess energy, resp. 213–219 g/d) significantly increased serum uric acid compared with the control diets in nondiabetic participants (mean difference = 31.0 mmol/L (95% CI: 15.4, 46.5)). Confounding from excessive energy could not be ruled out in the hyperenergetic trials, because no uric acid-increasing effect of tested fructose, isoenergetically exchanged with other carbohydrate, was noted in both non-diabetic and diabetic trials.

Zgaga et al. (2012) recently observed a positive association between plasma uric acid and SSB consumption but no association with fructose intake, leading the authors to suggest that fructose is not the causal agent underlying the SSB-urate association. In another cross-sectional study (Sun, Flickinger, Williamson-Hughes, & Empie, 2010), it was also concluded that higher dietary fructose intake was not associated with higher hyperuricemia risk in healthy adults. This is in line with the results of a meta-analysis (Livesey & Taylor, 2008) and review (Livesey, 2013) which refuted the relation between normal dietary consumption of sugars containing fructose and diabetes.

FINALIZING CONSIDERATIONS

As discussed, recent findings suggest that high or excessive fructose intake can induce certain metabolic alterations in both animal and human models. In this respect, thoughts regarding the potential harmfulness of excessive fructose and fructose-containing sugars intakes seem legitimate, especially in view of the high SSB consumption and the burdens of obesity and type 2 diabetes.

Based on the currently available data, however, any statement that ordinary fructose intake is toxic and that consumption of fructose-containing drinks are the leading cause of the global obesity epidemic is not supported by scientific consensus. We wish to highlight the findings of Gibson (2008), who re-examined the evidence from 40 observational and 4 intervention studies, as well as six reviews. She noted that the totality of the evidence was dominated by American studies and that most studies suggest that the effect of SSB is small except in susceptible individuals, involving genetic predispositions, psychological factors, and environmental stimuli (Ebbeling et al., 2006), or at excessive levels of intake (>20% of total energy). She reported that progress in reaching a definitive conclusion on the role of SSB in obesity is hampered by the paucity of good-quality interventions, which reliably monitor diet and lifestyle and adequately report effect sizes. Of the three long-term (6 months) interventions, one reported a decrease in obesity prevalence but no change in mean BMI and two found a significant impact only among children already overweight at baseline. Of the six reviews, two concluded that the evidence was strong, one that an association was probable, while three described it as inconclusive, equivocal or near zero.

Noteworthy is the work of Pollock et al. (2012), who observed in adolescents that higher fructose consumption is associated with multiple markers of cardio-metabolic risk, but when visceral adipose tissue was included as covariate, it attenuated these associations and showed that these relationships were mediated by visceral obesity.

Also, Rizkalla (2010) concluded that: "No fully relevant data have been presented to account for a direct link between dietary fructose intake and health risk markers". A re-evaluation of published epidemiological studies concerning the consumption of dietary fructose or mainly high-fructose corn syrup showed that most of these studies have been cross-sectional or based on passive inaccurate surveillance, especially in children and adolescents (Cullen, Ash, Warneke, & De Moor, 2002), and thus have not established direct causal links. Research evidence of the short or acute-term satiating power or increasing food intake after fructose consumption as compared to that resulting from normal patterns of sugar consumption, such as sucrose, remains unclear. Further, the negative conclusions regarding fructose have been drawn from studies in rodents or in humans attempting to elucidate the mechanisms and biological pathways underlying fructose consumption by using unrealistically high amounts of pure fructose. In this respect, we also want to draw attention to the results of a data analysis by Geoffrey Livesey (2009) who, based on the data of several large cohorts, concluded as follows:

> "Fructose is proving to have bidirectional effects. At moderate or high doses, an effect on any one marker may be absent or even the opposite of that observed at very high or excessive doses; examples include fasting plasma triglyceride, insulin sensitivity, and the putative marker uric acid. Among markers, changes can be beneficial for some (e.g., glycated hemoglobin at moderate to high fructose intake) but adverse for others (e.g., plasma triglycerides at very high or excessive fructose intake). Evidence on body weight indicates no effect of moderate to high fructose intakes, but information is scarce for high or excessive intakes. The overall balance of such beneficial and adverse effects of fructose is difficult to assess but has important implications for the strength and direction of hypotheses about public health, the relevance of some animal studies, and the interpretation of both interventional and epidemiological studies. By focusing on the adverse effects of very high and excessive doses, we risk not noticing the potential benefits of moderate to higher doses, which might moderate the advent and progress of type-2 diabetes, cardiovascular disease, and might even contribute to longevity." (Livesey, 2009)

CONCLUSION

Through multiple misconceptions about fructose and fructose-containing sugars, a causal role of their intake has been proposed in the etiology of the global obesity epidemic. However, current evidence on the metabolic effects of fructose, as consumed by the majority of populations, is insufficient to demonstrate such a role in metabolic diseases and the global obesity epidemic.

Given the impact of obesity and related metabolic diseases on health care costs, practical steps to prevent their development are obviously required. Nevertheless, implementing taxes on sugary foods and beverages as suggested is not supported by solid scientific evidence, and can be expected to be largely insufficient to address the whole issue of energy overconsumption (Sievenpiper & de Souza, 2013; Tappy & Mittendorfer, 2012). In this respect, one may rather aim at reducing the consumption of energy-dense foods, which represent a large panel of sweet and salted foods made largely available in shops, fast-foods, and restaurants. The food production and service industries would be welcome to play a responsible role by gradually limiting the amount of fat and added sugars in ready-to-eat or to drink products to reduce energy density. In addition, effective policies that facilitate and promote healthier diets and nutritious food alternatives should be encouraged.

Chapter 4

Back-of-pack information in substitutive food choices: A process-tracing study in participants intending to eat healthily

ABSTRACT

People are increasingly aware of the positive effects of a healthy diet. Concurrently, daily food consumption decisions – choices about both the quality and quantity of food that is ingested – are steered more by what consumers consider healthy. Despite the increased aim to eat healthier, however, consumers often do not read or incorrectly interpret on-pack nutrition information, resulting in suboptimal food choices in terms of health. This study aims to unravel the determinants of such inadvertent food choices from these consumers. In an online process-tracing study, we measured the actual usage of available back-of-pack nutrition information during substitutive food choices made by 240 participants who had the intention to eat healthily. Using mouse-tracking software in a computerized task in which participants had to make dichotomous food choices (e.g., coconut oil or olive oil for baking), we measured the frequency and time of nutritional information considered. Combined with demographic and psychosocial data, including information on the level of intention, action planning, self-efficacy, and nutrition literacy, we were able to model the determinants of inadvertent unhealthy substitutive food choices in a sequential multiple regression (R^2 = 0.40). In these consumers who intended to eat healthily, the quantity of obtained nutrition information significantly contributed as an associative factor of the percentage of healthy food choices made. Moreover, the level of correct answers in a nutrition literacy test, as well as taste preferences, significantly predicted the percentage of healthier choices. We discuss that common psychosocial determinants of healthy behavior, such as intention, action planning, and self-efficacy, need to be augmented with a person's actual reading and understanding of nutrition information to better explain the variance in healthy food choice behavior.

BACKGROUND

People in Europe and other industrialized countries are becoming more conscious about factors influencing their personal health (Brannon et al., 2014; Bugge, 2015). In addition to physical activity, the quality of the diet has become a well-known influence on a person's wellbeing, both by scientists as well as by the general population (Jallinoja et al., 2014; Jankovic et al., 2014; Swinburn et al., 2011). Therefore, governments (e.g., the European Food Safety Authority, World Health Organization) as well as companies (e.g., Nestlé, Unilever) have made specific recommendations to help people make healthier food choices (Nestle, 2013; WHO, 2013). These healthier food choices are one of the keys in putting a halt to the sky-rocketing obesity rates (Ng et al., 2014), obesity-associated health problems (Forouzanfar et al., 2015), and other diet-related health problems (Francis & Stevenson, 2013)

However, despite the widespread attention to the diet and the abundant recommendations to eat healthier, even health-conscious consumers, estimated to be about 50% of the European population (Jallinoja et al., 2014), often make dietary choices that do not benefit their health (Mötteli, Keller, Siegrist, Barbey, & Bucher, 2016). According to a recent study (Mai & Hoffmann, 2015), the level of health-consciousness has only a limited effect on improving one's diet – building on the fundamental premise that food choices are to a large extent driven by nonconscious processes. It appears that there is a mismatch between a person's health consciousness, their intention to eat healthier and their dietary behavior, partially explained by the conflict between eating enjoyment and health goals (Stroebe et al., 2013). A complementing explanation for this mismatch can be found in ineffective heuristics that people develop to make their food choices (Wansink et al., 2009). Strikingly, for example, there is a trend in which consumers have recently substituted products containing fructose (Welsh, Sharma, Grellinger, et al., 2011) or products containing wheat (Brouns et al., 2013) with the intention of improving their health. However, the substitution products (e.g., glucose-containing products or gluten-free bread) often do not result in an overall healthier diet in the general population (Missbach et al., 2015; Sievenpiper et al., 2014; Willett, 1994).

A major cause for this specific behavior is misleading information from food manufacturers, a widely studied phenomenon (Harris, LoDolce, & Schwartz, 2015). A lesser-studied reason in this context is the notion that consumers perhaps do not adequately process the available information and subsequently form maladaptive heuristics to reach their goals, while they actually perceive it as the right behavior (Mötteli et al., 2016). Given the increased emphasis on the consumer's responsibility in making healthy food choices (Hieke et al., 2015), we therefore feel that it is of crucial importance to understand what determinants play a role in substitutive food choices and food choice strategies in individuals who intend to eat healthily.

Theoretical background

A plethora of recent research is focused on finding effective interventions to increase the intention to eat healthily in individuals (often linked to low-socioeconomic (SES) consumers) (Escaron, Meinen, Nitzke, & Martinez-Donate, 2013). Such research builds on behavioral change theories that assume that the intention to change is the best predictor of actual change, such as the Theory of Reasoned Action, the Theory of Planned Behavior, or their successor the Reasoned Action Approach (Brannon et al., 2014). These theories offer limited guidance in explaining why people, despite intending to eat healthily, make unhealthy substitutive food choices. In these consumers who have a strong intention to change, actual behavior is sometimes not in line with this intention. As such, studying this particular group warrants a different theoretical approach to ensure the correct development of predictive models.

Fortunately, most stage-theories do acknowledge such a so-called intention-behavior gap (Sutton, 2005). In this respect, the health action process approach model (HAPA), a stage-theory based social-cognition model that describes the key stages and cognitions related to acting on an intention (Schwarzer, 1992; Schwarzer & Luszczynska, 2008), is of particular interest. The HAPA model emphasizes the particular role of self-efficacy, the extent of one's belief in one's own ability to reach goals, at different stages of health behavior change. As literature suggest that especially self-efficacy plays an important role in making healthy food choices made by people who already intend to eat healthily (Renner & Schwarzer, 2005; Richert et al., 2010), we opt to use this framework as a basis for our further study. A generic diagram of the HAPA model is depicted in Figure 4.

Healthy food choices have been successfully modelled in studies using the HAPA model. For example, Wiedemann, Lippke, and Schwarzer (2012) predicted fruit and vegetable intake by including the level of memory performance and number of action plans made by consumers. In another study in which 700 internet users from Germany participated, the HAPA model was found to be useful in predicting healthy dietary patterns (Schwarzer et al., 2007). Through structural equation modelling, the authors found that 73% of the dietary behavior variance in their data could be explained jointly by planning and self-efficacy using the HAPA model. Important to note here is that the measure of dietary behavior was constructed using participant responses on a 4-point scale in which they (dis)agreed with three similar statements regarding their intake of at least 5 fruits and vegetables per day – a rather simplified measure. In a similar study with Swiss participants, where a more complex measure of nutrition behavior was used (i.e., multiple items assessing ones adherence to an intended low-fat diet), only 34% of variance was explained by the change in HAPA-constructs including intentions, action planning and action control (Scholz, Nagy, Göhner, Luszczynska, & Kliegel, 2009). We therefore believe that dietary behavior should be measured close to the (complex) real-life behavior to ensure valid results.
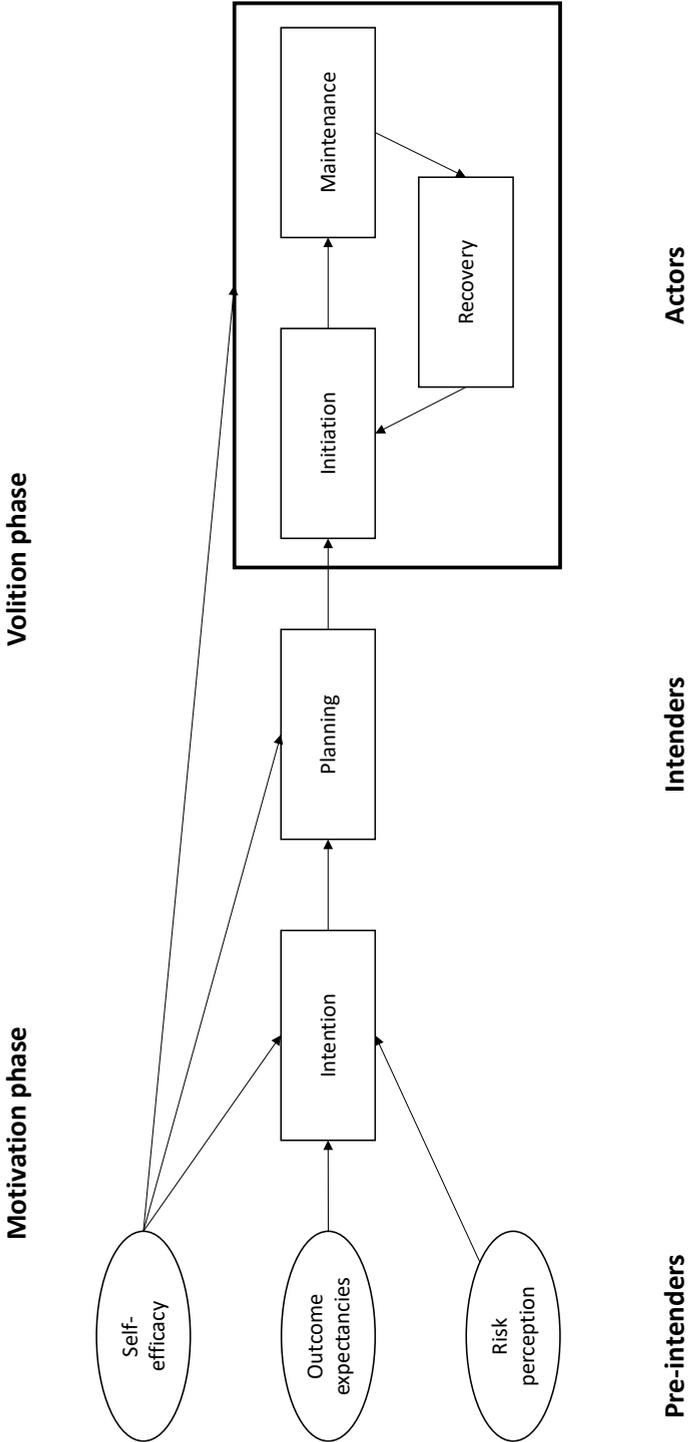
Figure 4: Generic diagram of the HAPA model (Schwarzer, 1992, 2008)

Modelling inadvertently unhealthy choices in the volition phase

While earlier studies have looked at the fit of the HAPA model on deliberate healthy dietary behavior, in particular fruit and vegetable consumption (Godinho et al., 2013; Radtke et al., 2014), only limited work has been done to understand how consumers intending to eat healthily inadvertently make unhealthy choices. To do so, clear operational variables that indicate the degree to which people process nutrition information when making food choices need to be combined with theoretically relevant variables such as nutrition literacy (Carbone & Zoellner, 2012), and other factors often associated with studies based on the HAPA model related to food choices (i.e., self-efficacy, intention, planning, and taste preferences). Nutrition literacy, in this respect, is defined as the degree to which people have the capacity to obtain, process, and understand basic nutrition information (Zoellner et al., 2009).

In this context, it can be assumed that individuals who intend to eat healthily are able to perceive the risk of unhealthy food consumption, understand the expected outcomes of changing behavior and believe that they are capable to exercise control of their actions. They have surpassed the pre-intention phase, have the intention to eat healthily, and are thus in the so-called volition phase. In this volitional phase, the degree to which people process nutrition information needs to be included in a model to understand their concrete food choices. In a recent systematic review (Vaitkeviciute et al., 2015), evidence on a positive association between the level of food information processing and adolescents' dietary intake was summarized. Although the available evidence was not conclusive, the authors posited that nutrition literacy – a relatively new concept, adapted from the term health literacy (Zoellner et al., 2009) might play an important role in shaping food intake decisions. Hence, Vaitkeviciute et al. (2015) concluded that nutrition literacy (termed food literacy in their review) needs to be included in models assessing food choices. According to them, rigorous research methods are required to effectively assess causality between food information processing and food choices. In addition to common demographic, socio-economic, and health psychological variables, models of food choices should therefore cover the quantity of information, and the capacity to apply this information when making food choices.

Conceptual model of determinants of the healthiness of substitutive food choices

We propose to contribute to the state of the art in the field of food consumption psychology and health promotion by giving an answer to the following research question:

> *What are the determinants of inadvertent (un)healthy substitutive food choices from consumers who have the intention to eat healthily?*

We defined these (un)healthy substitutive food choices as choices between two products, that have similar texture and taste when consumed, and as such can be easily substituted for one another, but differ significantly in their nutritional profile where one is considered the clear healthy option by nutrition experts.

To model the relevant factors that may contribute to these food choices, we build further on existing theory and empirical work (Luszczynska, Tryburcy, & Schwarzer, 2007; Sniehotta, Schwarzer, et al., 2005; Wiedemann et al., 2012; Zoellner et al., 2009), see also the previous section. It is hypothesized that demographic characteristics, intention to eat healthily, self-efficacy, planning, and taste preferences affect the quantity of information health and nutrition conscious individuals consider before making their choice. Furthermore, we posit that the healthiness of food choices is positively related to the level of nutrition literacy, as well as this quantity of information considered. In essence, we aim to test an adjusted HAPA model for the context of inadvertent unhealthy substitutive choices (see Figure 5).

METHODOLOGY

Study design and participants

In July 2016, we conducted an online process tracking study and survey in which Dutch-speaking consumers were asked to fill in an online questionnaire on their intentions to eat healthily, their related action plans, their food choice behavior, and their level of nutrition literacy. Participants were recruited through an online panel (http://academicresearchpanel.com/). Members of this online panel received an e-mail with a short introductory text and a link to a page that outlined the broad purpose of the study and information about inclusion criteria (i.e., >17 years of age, intending to eat healthily in the coming period, and using a computer with a mouse (no touch screen)). In our recruitment text and explanation, we stressed particularly to only continue if participants had the intention to eat healthily. Participants were asked to give their informed consent by checking boxes behind 4 statements, agreeing that they understood the purpose of the study, were informed about the inclusion criteria, understood that collected data was not linked to personal information, and were free to drop out at any time without giving a reason. In total, 240 participants complied with the inclusion criteria, provided informed consent, and completed the full set of questions and tasks in the online research. In Table 5, key characteristics of these participants are given.
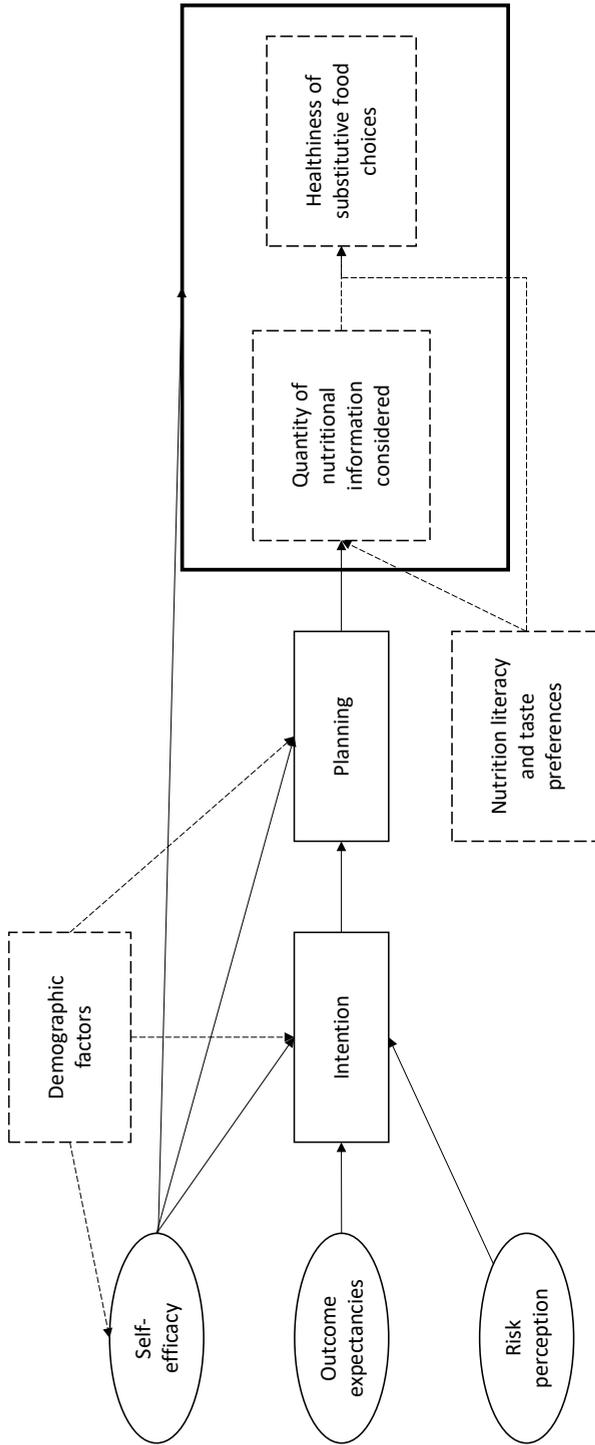
Figure 5: Conceptual model of hypothesized determinants of the healthiness of substitutive food choices made by health and nutrition conscious consumers, adjusted from the original HAPA model.

Table 5: Participant characteristics

	n (% of total)	Mean ± SD	Min – Max
Participants	240 (100%)	-	-
Females	148 (61.7%)	-	-
Males	92 (38.3%)	-	-
Age (in years)	-	51.65 (± 13.72)	17 - 88
BMI (kg/m^2)	-	25.42 (± 4.03)	16.71 - 39.64
Allergic	33 (13.8%)	-	-
Gluten	6 (2.5%)	-	-
Milk	13 (5.4%)	-	-
Crustaceans	5 (2.1%)	-	-
Other	9 (3.8%)	-	-
On a diet	69 (28.8%)	-	-
Vegetarian	13 (5.4%)	-	-
Education*	236 (98.3%)	-	-
Primary	1 (0.4%)	-	-
Secondary	52 (21.7%)	-	-
Tertiary	183 (76.2%)	-	-

* Primary education is only elementary school; secondary education includes preparatory middle-level vocational education (VMBO/MAVO or equivalent), higher general continued education (HAVO/VWO or equivalent); tertiary education includes intermediate vocational education (MBO/MTS or equivalent), higher professional education (HBO/HTS or equivalent) and scientific education (WO or equivalent).

Questionnaire

To find an answer to the research question, we have developed an online questionnaire in Dutch in which we included items for all typical constructs from the HAPA model: intention, self-efficacy, action planning, coping planning. All items were answered by (dis)agreeing to statements on a 7-point scale ranging from completely disagree (1) to completely agree (7). The intention to eat healthily was measured by translating and adapting items from Schwarzer and Renner (2000), e.g., "I intend to eat healthful foods over the next months". The self-efficacy construct was also measured by adapted items from Schwarzer and Renner (2000), e.g., "I can manage to stick to healthful food even if I have limited time". Action plans and coping plans were measured by translating and combining items based on the ones used in a variety of HAPA related studies (Luszczynska et al., 2007; Schwarzer et al., 2007; Sniehotta et al., 2006), e.g., "I have a detailed plan how to respond when someone offers an unhealthy snack". In this respect, action planning is a personal list of steps about when, where, and how one intends to act to achieve a goal. Coping planning includes the anticipation of barriers and the design of alternative actions that help to attain one's goals in spite of the impediments. The separation of the planning construct into two constructs, action planning and coping planning, has been found useful, as studies have confirmed the

discriminant validity of such a distinction (Schwarzer, 2008). Next to this, we added questions to determine demographic and psychosocial factors, such as gender, education level, marital status, allergies, if participants followed a diet, if participants were vegetarian, and physical activity. A summary of these participant characteristics is given in Table 5. Descriptive statistics and internal consistency of the key constructs from the HAPA model including nutrition literacy and taste preferences are given in Table 6.

Nutrition literacy, one of the key constructs of this study, was also measured. From the several nutrition literacy scales developed and reviewed recently (Carbone & Zoellner, 2012; Haun, Valerio, McCormack, Sørensen, & Paasche-Orlow, 2014; Velardo, 2015), the Nutrition Literacy Scale (NLS) has received most praise and was validated, also by dietitians, in multiple studies (Diamond, 2007; Nguyen et al., 2015). The NLS consists of a series of statements in which a part of a sentence is left blank (e.g., "Calcium is _____ for bone health". Participants are presented four options (e.g., "essential", "osteoporosis", "expensive", "prescription") and asked to pick the one that makes the most sense to them to complete the statement. We have translated and slightly adapted the items to fit the Dutch situation (e.g., ounces to grams). Six of the original twenty-eight items were not included because of a poor fit to the nutrition literacy construct for our study (e.g., questions related to the price of healthy foods and weed-control techniques of organic foods).

Table 6: Descriptive statistics and internal consistency of the key constructs from the HAPA model including nutrition literacy and taste preferences

	Mean ± SD	Range (min – max)	Cronbach's alpha
Intention to eat healthily (7 items)	5.55 ± 0.90	1.86 – 7.00	0.849
Self-efficacy (9 items)	5.19 ± 1.04	1.00 – 7.00	0.919
Action self-efficacy (2 items)	5.13 ± 1.31	1.00 – 7.00	0.829
Coping self-efficacy (7 items)	5.20 ± 1.08	1.00 – 7.00	0.889
Action planning (6 items)	3.88 ± 1.56	1.00 – 7.00	0.906
Coping planning (7 items)	3.88 ± 1.60	1.00 – 7.00	0.944
Nutrition literacy (correct answers in 22 items)	18.62 ± 2.30	5 – 22	-
Taste preference score*	19.71 ±2.612	9.00 – 27.00	-

* Aggregated score ranging from a taste preference for the unhealthy option (9) to the healthy option (27). Full description of variable is given in text of next subsection.

Measurement of quantity of nutritional information

Building on a 2007 computer-based experiment on food choices (Scheibehenne et al., 2007), in which first evidence was found that people can be classified into the process they use to make food decisions, we used the open source program MouselabWeb 1.00 beta (Willemsen & Johnson, 2011) to quantify food choice behavior. Similar to another

computer-based experiment using pictures of canteen lunches (Schulte-Mecklenbeck, Sohn, de Bellis, Martin, & Hertwig, 2013), we aimed to find what on-pack (nutrition) information was utilized to make (un)healthy substitutive food choices. In our study, we asked participants to choose between nine pairs of common food products that can be purchased in supermarkets. Of each product, the name and picture were given and participants had the option to view eight more attributes in a matrix form, echoing the design of food labels. Participants were asked which of the two products they would purchase for a price acceptable to them and were instructed not to base their decisions on taste (Figure 6). By explicitly stating that price and taste were not relevant to their choice, we aimed to minimize the effect of these factors on their food choice behavior. In doing so, we could measure nutrition information usage on a choice based on perceived product healthiness – rather than tastiness or price."

At the beginning of each choice, all pieces of nutrition information on product attributes were concealed. Participants could open a cell by moving the cursor over it; the cell closed when the cursor was moved away. Using the MouselabWeb software, both the frequency and time of opened cells were tracked and stored on the university server on which the online questionnaire was hosted.

The matrix consisted of two columns, each representing one food product. Each column contained the product's name, its image, and eight nutritional attributes (ingredient declaration, calories, total carbohydrates, sugars, total fat, saturated fat, protein, and salt). The position of the foods in the columns (left/right) was counterbalanced between choices and participants. The closed attributes were also counterbalanced in terms of the row in which they appeared, but remained linked with the appropriate column (product). Participants read detailed instructions about how to use MouselabWeb and conducted a guided practice trial before starting with the substitutive food choice tasks (Schulte-Mecklenbeck et al., 2013).

In our analysis on nutrition information considered, we only included data where participants opened a cell for more than 100ms. Acquisitions <100ms cannot have been read and comprehended by the participant (M. A. Just & Carpenter, 1980) and were likely the result of involuntary or accidental openings when scrolling over the page. In our analysis on food choice behavior, we excluded the choices that participants made for products that they were allergic to, or had a medical condition prohibiting consumption. These choices were not counted towards their score of healthy choices made. For example, for those participants who were allergic to peanuts, the percentage of healthy choices was calculated using only the 8 choices (instead of the total 9) in which products were shown that did not contain peanuts (see also Table 9).

Figure 6: A screenshot of a choice matrix provided in MouselabWeb. All cells listing nutritional and ingredient information were closed unless the cursor was moved over them. In this screenshot, the amount of carbohydrates of the "Speltbrood" (spelt bread) is viewed by a participant.

The 9 food choices were all concrete examples listed on the website of the Dutch Centre for Nutrition (Voedingscentrum, 2016), see Table 7. This institute uses the so-called Wheel of Five (Dutch: De Schijf van Vijf), to give straightforward nutrition advice. On the website of this tool, specific recommendations are provided giving clear examples of what is not advised, and how it can be substituted (e.g., eating whole-wheat bread instead of refined spelt bread).

Table 7: The 18 food products (9 dichotomous choices) presented to participants.

Choice:	Unhealthy choice*:	Healthy choice*:
1	Gouda Cheese 48+**	Gouda Cheese 30+**
2	Coconut oil	Olive oil
3	Spelt bread (refined)	Whole-wheat bread
4	Canned string beans (with added salt)	Frozen string beans
5	Culinary pork loin (injected with water and additives)	Pork loin
6	Calvé Peanut butter (with more fat and salt)	100% Peanut butter
7	Santa Maria Extra Fine Selection Thai Red Curry (with added salt)	Original Spices by Jonnie Boer Thai Red Curry
8	Salted full-cream butter	Liquid baking fat (from vegetable oils)
9	Feta 45+	Goat cheese 45+

* Participants saw Dutch names without information between brackets and a picture
** The numbers indicate the fat content of the cheese, based on the percentage of milkfat solids – a common way of indicating cheese differences in the Netherlands.

After participants have made all initial food choices, they were asked to make the same choice again – without having the option to view additional attributes – solely based on taste and the product description and picture. Taste preference values were coded as "1" when they had a taste preference for the unhealthy option, as "2" when they indicated not to have a preference for both options, and "3" when they had a taste preference for the healthy option. The recorded values per choice were aggregated into a continuous variable ranging from a general taste preference for the unhealthy option (9), to a general taste preference for the healthy option (27).

Ethical approval
The Open University's ethical review committee (cETO) reviewed the research proposal. The scope of the research, the informed consent procedure, the contents of the questionnaire, and the possible physical and psychological impact on participants were assessed and approved (reference: U2016/03880/FRO).

Pilot study
To ensure adequate understanding, we ran a small (qualitative) pilot study before the main study in a convenience sample of 20 participants that fit the inclusion criteria from our personal network. By testing the study procedure and materials first, we could make some necessary improvements in functionality and comprehensibility. We particularly improved the instructions before some sets of questions, as well as simplified wordings of questions to aid understanding. A native English speaker checked all constructs that were adapted and translated from their original English wordings.

Statistical analyses

To test our hypotheses, statistical analyses were performed using the IBM SPSS Statistics software version 22. Descriptive statistics of the study population and correlations between all main variables were calculated. Only participants who completed the full study were included in the analyses (n = 240).

Using a sequential hierarchical multiple regression analysis, we determined how much demographic variables, intention to eat healthily, action planning, coping planning, taste preferences, nutrition literacy, self-efficacy, and the time and number of attributes considered could explain the percentage of healthy food choices made. The hierarchical linear model (HLM) followed the proposed conceptual model. We first modelled the effect of demographic variables on the healthiness of food choices (Model 1), followed by the psychosocial characteristics of the participants (Model 2). In Model 3, nutrition literacy was included. In the full model (Model 4), the quantity of nutritional information considered was added. The improvement of the model is expressed in the added, unique variation in the healthiness in food choices (R^2) that they explain.

Linearity of the models was assessed by the partial regression plots and a plot of studentized residuals against the predicted values. In the four models, there was independence of residuals, as assessed by a Durbin-Watson statistic within range of 1.850 – 2.150. There was homoscedasticity, as assessed by visual inspection of a plot of studentized residuals versus unstandardized predicted values. There was no evidence of multicollinearity, as assessed by tolerance values greater than 0.1. There were no studentized deleted residuals greater than ±3 standard deviations, no leverage values greater than 0.2, and values for Cook's distance above 1. There assumption of normality was met, as assessed by Q-Q Plots.

RESULTS

Food choice behavior

As can be seen in Table 8, participants made on average 82.16% (± 17.42%) healthy food choices. An average of 21.02 information-cells (± 8.50 (SD)) were opened to view the nutritional information per substitutive food choice. As there were only 16 information-cells available per choice (8 cells with separate food attributes per product), participants often opened cells more than one time. Per substitutive choice, participants opened cells for an average time of 18.72 seconds (± 9.38 (SD)) (Table 8).

Table 8: Descriptive statistics of the amount and time of nutritional information considered, taste preferences, and percentage of healthy food choices

	Mean ± SD	Range (min – max)	Cronbach's alpha
Number of information-cells opened per choice (9 choices)	21.02 ± 8.50	2.00 – 56.22	0.883
Time used to view information-cells per choice (in seconds; 9 choices)	18.72 ± 9.38	1.00 – 46.01	0.871
Percentage of healthy food choices (from max. 9 matrices)	82.16 ± 17.42	25.00 – 100.00	-

As described in the Methodology section, the percentage of healthy food choices was adjusted to the number of choices that were relevant to the participant (allergies, health conditions and vegetarianism were controlled for). The choices that participants made for products that they were allergic to, or had a medical condition prohibiting consumption, were not counted towards their score of healthy choices made. In Table 9, the choices per food pair are listed and the number of exclusions are given.

Table 9: Choices per food pair, taking into account relevant allergies, health conditions and vegetarianism

Choice:	Unhealthy choice (% of total):	Healthy choice (% of total):	Excluded (% of total) incl. reasons for exclusion*:
Cheese (48+ vs. 30+)	36 (15.0%)	168 (70.0%)	36 (15.0%) 13 allergic to milk 25 vascular problems
Cooking oil (coconut vs. olive)	23 (9.6%)	192 (80.0%)	25 (10.4%) 25 vascular problems
Bread (refined spelt vs. whole-wheat)	36 (15.0%)	184 (76.7%)	20 (8.3%) 6 wheat allergy 14 irritable bowel syndrome 5 Crohn's disease / colitis ulcerosa
String beans (canned vs. frozen)	15 (6.3%)	225 (93.8%)	0 (0%)
Pork loin (injected vs. non-injected)	12 (5%)	187 (77.9%)	41 (17.1%) 41 vegetarian
Peanut butter (with additives vs. 100% peanuts)	59 (24.6%)	179 (74.6%)	2 (0.8%) 2 peanut allergy
Red curry spices (added salt vs. no added salt)	28 (11.7%)	187 (77.9%)	25 (10.4%) 25 vascular problems
Cooking oil (butter vs. vegetable oils)	75 (31.3%)	129 (53.8%)	36 (15.0%) 13 allergic to milk 25 vascular problems
Cheese (feta vs. goat cheese)	65 (27.1%)	139 (57.9%)	36 (15.0%) 13 allergic to milk 25 vascular problems

* Participants can be excluded for more than 1 reason. The combined reasons can therefore be larger than the total excluded participants.

Modelling healthy substitutive food choice behavior

Correlations between all variables that were included in the main analyses are shown in Table 10. Significant correlation between the background variables and some of the main variables were found; including significant correlations between nutrition literacy, quantity of nutritional attributes considered, and the percentage of healthy food choices made. In line with theory, also significant correlations were found between intention to eat healthily and self-efficacy, action planning, and coping planning. Both intention to eat healthily and nutrition literacy correlated significantly with any other variable except age.

Table 10: Correlations between all main variables (N = 240)

	1	2	3	4	5	6	7	8	9	10	11	12
1. Gender	-	.09	.25*	-.29*	-.21*	-.26*	-.31*	.09	-.12*	.01	.06	.01
2. BMI		-	.17*	-.12*	-.17*	.01	.03	.07	-.17*	.09	.06	-.02
3. Age			-	-.16*	-.09	-.03	-.01	.04	-.01	.24*	-.02	-.02
4. Intention to eat healthily				-	.66*	.56*	.54*	.14*	.25*	.14*	.15*	.16*
5. Self-efficacy					-	.54*	.60*	.13*	.26*	.02	-.02	.03
6. Action planning						-	.79*	.11*	.19*	.14*	.10	.09
7. Coping planning							-	.10	.20*	.12*	.05	.08
8. Taste preference								-	.13*	.11*	.12*	.39*
9. Nutrition literacy									-	.15*	.13*	.27*
10. Time of att. considered										-	.81*	.43*
11. # of att. considered											-	.50*
12. % of healthy choices												-

* p < 0.05

In Table 11, the results of the sequential multiple regression analysis are shown. The addition of each set of variables led to a statistically significant increase in R^2 (p < .05) The full model (Model 4) to predict the percentage of healthy food choices was statistically significant, $R^2 = .40$, $F(11, 228) = 13.823$, p < .0001, adjusted $R^2 = .371$.

In the full model, we observed that taste preference, nutrition literacy, and number of attributes considered all significantly contributed as associative factors of the percentage of healthy food choices made (p < 0.005). Remarkably, intention to eat healthily and self-efficacy are significant contributors in Model 2 and 3 (p < 0.05), but not in Model 4 (p = 0.489 and p = 0.161 respectively).

Table 11: Associative factors of the percentage of healthy choices made (N = 240)

	Variables	β	t	p	R^2
Model 1					0.001
	Gender	0.017	0.254	0.800	
	BMI	-0.017	-0.261	0.794	
	Age	-0.021	-0.312	0.755	
Model 2					0.182
	Gender	0.017	0.258	0.797	
	BMI	-0.059	-0.948	0.344	
	Age	-0.014	-0.215	0.830	
	Intention to eat healthily	0.191	2.230	0.027*	
	Self-efficacy	-0.191	-2.189	0.030*	
	Action planning	-0.004	-0.039	0.969	
	Coping planning	0.066	0.624	0.533	
	Taste preference	0.386	6.323	<0.001*	
Model 3					0.229
	Gender	0.030	0.472	0.638	
	BMI	-0.024	-0.393	0.694	
	Age	-0.026	-0.419	0.676	
	Intention to eat healthily	0.205	2.287	0.023*	
	Self-efficacy	-0.216	-2.535	0.012*	
	Action planning	-0.005	-0.047	0.962	
	Coping planning	0.054	0.522	0.602	
	Taste preference	0.361	6.037	<0.001*	
	Nutrition literacy	0.232	3.742	<0.001*	
Model 4					0.400
	Gender	-0.014	-0.246	0.806	
	BMI	-0.052	-0.957	0.340	
	Age	-0.026	-0.429	0.668	
	Intention to eat healthily	0.052	0.693	0.489	
	Self-efficacy	-0.108	-1.406	0.161	
	Action planning	-0.045	-0.525	0.600	
	Coping planning	0.058	0.641	0.522	
	Taste preference	0.325	6.118	<0.001*	
	Nutrition literacy	0.171	3.118	0.002*	
	Time of attributes considered	0.055	0.557	0.578	
	# of attributes considered	0.389	4.026	<0.001*	

β = standardized coefficient; * = p < 0.05

DISCUSSION

Despite having a relatively high average intention to eat healthily (5.55 on a 7-point scale), and a relatively high average sense of self-efficacy (5.19 on a 7-point scale), an average of 82.16% of the dichotomous substitutive food choices resulted in the healthy option in our experiment. This roughly means that one in five substitutive food choices would result in the unhealthy food choice. These findings partially confirm the often observed mismatch between intention to eat healthily and actually making healthy food choices – even within our specific subgroup and using an online study. Although 82.16% seems high, with an estimated 200 food decisions per day (Wansink & Sobal, 2007), increasing this percentage could result in substantial health benefits for highly-educated health-minded individuals. Moreover, we expect that in reality the percentage of healthy choices will even be lower as other factors (time, taste, price) would affect the substitutive food choice decisions (Glanz, Basil, Maibach, Goldberg, & Snyder, 1998).

Our findings suggest that improving one's actual reading and understanding of nutrition information has a direct effect on making healthier substitutive food choices. Moreover, our methodology provides a unique insight in the relativity of determinants that are associated with healthy choices. In our final model, only taste preferences, nutrition literacy, and the quantity of nutrition information considered significantly predicted the healthiness of food choices, while more social-cognitive models (Model 2 and Model 3) exposed the importance of intention to eat healthily and sense of self-efficacy – which are relatively high in this group.

Remarkably, in our study, self-efficacy had a significant negative effect on the percentage of healthy food choices made in Model 2 and Model 3. Over-confident individuals who overestimate their own abilities to make healthy choices could explain this finding. Regardless, the influence of intention and self-efficacy was not-significant when the number of attributes considered was added to the model (Model 4).

We find that to better explain the variance in food choice behavior for this particular population, commonly used variables in the HAPA model (i.e., intention, planning, and self-efficacy) need to be augmented with nutrition literacy and a measure for nutrition information considered.

The effect of nutrition literacy on substitutive food choices

Health literacy, defined as the ability to obtain, read, understand and use health-related information to make appropriate health decisions, has been proven to have a positive effect on health-outcomes, including the incidence of medical conditions such as obesity and diabetes (R. M. Parker, Baker, Williams, & Nurss, 1995; Schillinger et al., 2002). As nutrition has a major impact on many chronic diseases, the sub-concept of nutrition literacy has been proposed in the last decade (Silk et al., 2008). In our study, increased nutrition literacy, measured using the validated NLS (Diamond, 2007; Nguyen

et al., 2015), had a significant positive effect on the percentage of healthy substitutive food choices made in our study.

In our analysis, we found that nutrition literacy had a stronger effect on the percentage of healthy food choices made than the intention to eat healthily. Albeit not as strong as the frequency of nutrition information considered, nor as strong as a person's taste preferences (see Table 10), nutrition literacy is a significant determinant of the composition of the diet of highly-educated health-minded individuals. In this respect, we argue that nutrition literacy should be increased, perhaps through incorporating it in (high-school) curricula or through other public health campaigns (Velardo, 2015). This should be done not only in health-minded individuals, but also in the general population as it helps to better read and understand (on-pack) nutrition information, which could result in healthier choices (Gibbs & Chapman-Novakofski, 2013; Rothman et al., 2006). There should be a specific focus on to increase nutrition literacy in lower-educated individuals, perhaps through targeted public health campaigns.

The effect of consulting nutrition information on substitutive food choices

In health-minded adults from our study, we observed a direct beneficial effect of the actual reading and understanding of specific nutrition information on the healthiness of substitutive food choices made. This finding complements research in which the inclusion of nutrition information was manipulated, e.g*.,* by including calorie information next to menu items (Kozup et al., 2003) or by explicit simplified front-of-pack information (Hodgkins et al., 2015). We argue, however, that simplified 'at-a-glance' information is only there to supplement the information that is provided on the back-of-pack. By only utilizing part of the information (e.g., low-fat or gluten-free), consumers are prone to still make unhealthy choices.

We observed a direct effect of the quantity of information considered, in particular utilizing multiple different pieces of information, and the healthiness of choices made. In Model 4, there was no significant effect of the time of attributes considered on the percentage of healthy food choices made. This can be explained by the high correlation between the time and number of attributes considered (see Table 10). It appears that the variance of the time of the attributes considered is eliminated when the quantity of attributes is included in the model. Although there is a high correlation of time of attributes considered and percentage of healthy choices, the inclusion of another highly correlated variable (quantity of attributes considered) renders the direct effect not significant.

Current public health interventions often focus on improving the intention to eat healthily and on stimulating the use of action and coping plans to facilitate healthy food choices. Our findings suggest that, even when people are highly motivated, it should not be forgotten by policy makers and food industry that people need to turn around a

product and read and correctly interpret the available information that is placed on pack as required by law in order to facilitate healthy food choices. Our findings suggest that this would be beneficial to reduce the currently often-observed intention-behavior gap in making food choices. Evidently, using a stage-based model as basis for our research, it should be noted that this strategy is only applicable for consumers that are already prepared to take such action - so consumers who have passed the pre-intention phase.

Process-tracing in food choice studies

To measure substitutive food choices, we have further developed a tool to measure food choices (Scheibehenne et al., 2007). Using this tool, we were able to track the frequency and time of attributes considered before making a substitutive choice. Augmenting earlier studies that used fruit and vegetable consumption as a proxy for healthy food choices (Godinho et al., 2013; Radtke et al., 2014), we used a more complex tool to measure this behavior. Although maybe far from real-life behavior, the tool used measures behavior without causing a great difficulty on the part of the decision-maker - in this study the participant who had to choose between two food products. The cognitive processes related to making food choices are very quick, fragile, often based on heuristics, and prone to be affected by measurement itself. By not asking explicitly about what nutrition information is considered prior to making a choice, and by accurately measuring how long participants hover over specific information, we can quantify better the nutrition information acquisition patterns in food choice tasks. By quantifying this behavior, a better understanding in terms of change in food choice behavior, can be developed and used to guide future interventions (Chandon & Wansink, 2011).

In our final model, we reached an R^2 of 40.0% (adjusted R^2 = 37.1%). Although there is undoubtedly room for improvement, other HAPA-derived models on food choices have reached considerably lower numbers. For example, in the study by Luszczynska et al. (2007), only 12% of the variance in fruit and vegetable intake could be explained by the independent variables used in their model. Lange et al. (2013) found that 23% of the fruit intake variance measured in their study was accounted for. Schwarzer and Renner (2000) reported a similar model fit, with 40% of dietary behavior of South-Korean women explained (33% in South-Korean men). As introduced in this paper, Schwarzer et al. (2007) found that 73% of the dietary behavior variance in their data could be explained in their study, but the measure of dietary behavior (e.g., self-reported questions on fruit-intake) was much more simplified compared to our and other measures, potentially elevating the model fit. In this respect, Lippke et al. (2009) substantiate that when applying stage-models, such as the HAPA model, correct classification of behavior is of utmost importance to produce reliable conclusions.

Limitations of our investigation

Although this study provides relevant findings to further improve the applicability of the HAPA model and related cognitive models on understanding food-related behavior, there are some limitations that need to be addressed. Most prominently, most individuals generally do not make food choices on a computer yet (barring the growing number of online grocery shoppers). Our results show that people consult nutrition information for an average of 18.72 seconds prior to making a substitutive food choice. In real life, such choices are likely made much quicker – even when carefully considering unknown (new) products and assessing them on nutrition information. As such, the use of an online research panel limits the generalizability of our study. That being said, over the years, it has become clear that there are only limited differences between outcomes using an online convenience sample relative to laboratory-based off-line research in social psychology (Casler, Bickel, & Hackett, 2013; Riva, Teruzzi, & Anolli, 2003). Moreover, a similar study in real life would require participants to wear eye-tracking devices – which have their own limitations and also lack realism for study participants (Graham et al., 2012).

Although the benefits of full random sampling are understood, we opted for the less ideal convenience (opportunity) sampling to find such participants for this research, as it requires less money, effort, and time. Most determinant studies in health psychology (e.g., Godinho et al., 2013; Schwarzer et al., 2007) have similarly refrained from using full probability sampling techniques as the relative cost and time required to carry out such research are too high and do not outweigh the potential bias.

The demographic characteristics in our study are not quite comparable to the general Dutch population. Our participants were considerably more educated, with 76.2% having received tertiary education as compared to the population average of 27.6%, and comprised more of women (61.7% in our study vs. 50.4% in the Dutch population) (Statline, 2016). As mentioned, we specifically recruited individuals who were >17 years of age, intending to eat healthily in the coming period, and using a computer with a mouse (no touch screen). These inclusion criteria could explain the differences in demographic characteristics from the general population, including the relatively high mean age and the high average intention to eat healthily. These characteristics might also explain the negative effect of self-efficacy on the percentage of healthy food choices in Model 2 and Model 3, if we assume that the high-level of education might be related to being over-confident about ones self-efficacy with regard to making correct food choices.

Implications for practice

In our analysis, we find that nutrition literacy is a significant predictor of healthy substitutive food choices. The current main point of focus in improving nutrition literacy

is improving nutrition education. For health professionals and schools, this might mean to dedicate a larger part of the formal education to nutrition (Chung, van Buul, Wilms, Nellessen, & Brouns, 2014). For the general public, web-based computer-tailored nutrition education could be key (Oenema, Brug, & Lechner, 2001). As food consumption decisions are made in an apparent mindless fashion and are very habitual (Wansink et al., 2009; Wansink & Sobal, 2007), however, we argue that increasing nutrition literacy needs more than mere education. Not only do consumers need to obtain and understand information, they should also be able to apply it in the split-second food decisions they make throughout the day, when shopping for food, etc.

In this respect, the development of more complex heuristics used in daily food consumption decisions, which often take place automatically, need to be considered. Future research could for instance focus on developing interventions in which the necessary hand movements when products are taken of a shelf to view the back of a food pack are promoted. Currently, only a limited percentage of the population reads the nutrition information on the back-of-pack (16.8% of European consumers, according to one study (Grunert et al., 2010)). Not only may the information be too complex for those who have most health-problems, such as the lower socioeconomic and/or less educated part of the population, there is also much room for improvement in the design of these labels. As such, food industry professionals are urged to consult best-practices in terms of design, location on pack, and font (Graham et al., 2012).

Conclusion and suggestions for future research

Recent media-attention has yet again focused on the susceptibility of health-minded consumers to develop heuristics that lead to unhealthy food choices – masked by simplified conclusions from unreliable data (Pieters, 2016). As introduced, the root of this phenomenon warrants a better understanding to ensure that one's actions are better in line with their intentions. It appears that health-minded consumers should focus more on obtaining multiple pieces of simple nutrition information (e.g., the whole nutrition table) rather than to focus on simplified nutrition related messages alone (e.g., sugar-free). Policy makers as well as industry decision makers should therefore focus more effort in improving nutrition literacy and product attribute communication for healthier food choice behavior.

In future studies, we suggest to replicate this experiment in a population which does not have a high intention to eat healthily and low-SES consumers to better understand the relativity between the studied attributes and nutrition literacy across populations. Moreover, an in-depth analysis is warranted on the precise attributes that individuals consider – related to their psychosocial characteristics. Understanding why some individuals merely focus on salt-levels, for instance, while others focus on calories and sugar, could be of interest to food industry and public health professionals alike.

Chapter 5

Choosing the lesser of four evils: A cluster-analysis on usage of energy, salt, sugar, and saturated fat-information in food choices

ABSTRACT

Regular intake of foods high in energy and added salt, sugar, and saturated fat is a risk factor for developing overweight, metabolic disorders, and related diseases. Health-conscious consumers should therefore consult available information on these four "evils". It has become apparent, however, that some consumers do this more than others do. In this study, we investigate differences between health-conscious consumers clustered on their usage of energy, salt, sugar, and saturated fat-information. We hypothesize that intention to eat healthily, planning abilities, perceived self-efficacy, nutrition knowledge, and taste-preferences predict the level of information considered – and thus healthy choices. Using process tracing software in a computerized task in which participants made dichotomous food-preference choices on comparable products (e.g., high-fat vs. low-fat cheese), we measured the frequency and time of nutritional information considered. We found three groups of participants that clustered on energy, salt, sugar, and saturated fat information used. Between those clusters, we found a difference between how often, on average, the healthy option was chosen (88.95% with high information usage vs. 67.17% with low information usage). Moreover, through a nominal logistic regression, we found that presence in a particular cluster of participants could be predicted by one's perceived self-efficacy in making healthy choices and intention to eat healthily. Remarkably, consumers with high self-efficacy and low intention to eat healthily appear to consult less information on energy, salt, sugar, and saturated fat. This could mean that some health-conscious consumers are overconfident in their ability to make healthy choices and use less cognitive processing. These findings help understanding conditions to develop effective interventions targeted at health-conscious consumers.

INTRODUCTION

In the last decades, it has become overwhelmingly clear that regular intake of foods high in energy and with added salt, sugar, and saturated fat are among the key risk factors for developing overweight, metabolic disorders, and related diseases (O'Neill & O'Driscoll, 2015). As such, on-pack information on these nutrients and level of energy should be consulted by consumers prior to making a food choice, in case the food product characteristics are not already known (Hoefkens, Verbeke, & Van Camp, 2011). Through front-of-pack nutrition claims (e.g., 'low sugar'), public health campaigns (e.g., increasing consumer awareness of salt intake), and food reformulation affecting back-of-pack nutrition information (e.g., lowering saturated fat levels and/or energy of processed foods), consumers are urged to choose foods with a more optimal nutrient composition (He, Brinsden, & MacGregor, 2014; Van Buul & Brouns, 2015).

However, despite both governmental and industrial efforts to improve the quality of food choices, we observed in a recent study (Van Buul, Bolman, Brouns, & Lechner, 2017) that there seems to be a subset of consumers who only limitedly take into account the available nutrition information. In this respect, multiple studies have shown large heterogeneity in health-conscious consumers in terms of usage of important predictors of healthiness of foods (Bornkessel, Bröring, Omta, & van Trijp, 2014; Ellison, Lusk, & Davis, 2013; Mai & Hoffmann, 2015; Wardle, 1993). Moreover, in a qualitative study in UK based females (Wahlich, Gardner, & McGowan, 2013), it was found that even if available nutrition information was consulted, the conversion to appropriate action was barred by an array of factors, including competing messages at the point-of-purchase. Apparently, subgroups of consumers who have the intention to make healthy choices are not succeeding in improving the quality of food choices by consulting and interpreting back-of-pack information (Zandstra, Lion, & Newson, 2016).

Although these consumers believe that they do make healthy choices, they in fact make a less healthy choice (e.g., by choosing less healthy coconut oil over healthier olive oil for baking). However, in case more time would have been spent on the available nutrition information (i.e., saturated fat content of the oils), they would have been directed towards a healthier choice; in this case olive oil.

For public health, individuals who have a strong intention to eat healthy foods are of great interest. This group is motivated to eat healthily, something which is a hard-to-convey prerequisite for true healthy eating behavior according to current health psychological theory (Brannon et al., 2014). Only in later stages in the theoretical pattern of moving from intention to behavior, there appears to be a hitch in actual healthy behavior (Sutton, 2005). Our main research question therefore is to unravel who these people are, what their characteristics are, and whether they can be grouped in certain sub groups showing similar patterns. In this respect, we need to understand and list differences between individuals who have the intention to eat healthily with respect to their use of available nutrition information. In doing so, we aim to predict

"membership" of these subgroups based on their demographic and/or psychosocial characteristics. This will ensure appropriate development of innovative, evidence-based, policies and interventions that will enhance people's ability to create and maintain healthy behavioral practices (Rothman et al., 2015).

With regard to the important psychosocial variables that could differ between consumers, we focus on the Health Action Process Approach (HAPA) model, a social-cognition model that describes the key stages and cognitions related to acting on an intention (Schwarzer, 1992). In earlier studies (Godinho et al., 2013; Lippke & Plotnikoff, 2014; Van Buul et al., 2017), this model provided an interesting framework of psychosocial variables that can partially explain differences in food choice behavior. In the HAPA model, different theoretical insights are combined to explain how people can become aware of their personal health, intend to change it, and the dynamic process that follows this intention. According to the model, through a motivation and volition stage, people can develop intentions to be more healthy (motivation) and subsequently act on these intentions (volition). In this volition phase, one can distinguish two groups of individuals: those who have not yet translated their intentions into correct action, and those who have. The split between different stages makes the theory relevant for the problem at hand. In fact, we want to investigate the existence of subgroups of consumers that are willing to eat healthily – but are not doing so – along with groups of with consumers who are not even willing to eat healthily.

In our research, we assume that consumers who have the intention to eat healthily recognize the risk of unhealthy food consumption. As such, they should understand the expected outcomes of changing behavior, and are capable to exercise control of their actions. (Springvloet, Lechner, & Oenema, 2014). They have surpassed the pre-intention phase. As such, we assume differences in how well these intentions are transformed to behavior within this still heterogeneous group. Next to that, we assume that there are more factors at play in this complex relationship. Earlier studies have shown that nutrition literacy (Carbone & Zoellner, 2012; Rothman et al., 2006) and taste preferences (Ebneter et al., 2013; Raghunathan et al., 2006) have a profound influence on food choice behavior and accordingly health.

NUTRITION INFORMATION CONSIDERATION IN CONSUMERS INTENDING TO EAT HEALTHILY

There has been an abundance of studies investigating the effect of incorporating nutrition information (e.g., through menus, on-pack information, in restaurants, etc.) in the food choices of various populations (e.g., Ellison, Lusk, & Davis, 2012; Grunert et al., 2010; Kozup et al., 2003). With this, there is a growing body of evidence that not all ways of presenting nutrition information to the consumer can be treated equally and/or have the equal desired effect in food choice. For instance, simplified front-of-pack single

nutrient claims, particularly 'low-fat', could be barring the general public to make healthier choices (Ebneter et al., 2013).

To the best of our knowledge, however, there have not been studies focusing specifically on whether and how nutrition information, regardless of how it is presented, is used and perceived by consumers who have the intention to eat healthily. Moreover, in most studies towards the relationship between nutrition information and behavior, the available nutrition information itself is manipulated between the groups that are studied, rather than measured and compared within a group (Mhurchu et al., 2017). As we aim to study within-group differences to understand better the heterogeneity, we feel there is a paucity of knowledge in this area that needs further study. Building on our broad theoretical psychological model of the determinants of inadvertent unhealthy substitutive food choices from our earlier study (Van Buul et al., 2017), this current study aims to provide concrete suggestions on how nutrition behavior can be improved through differentiation between consumers who all have the intention to eat healthily, but differ on nutrition information usage and psychosocial characteristics. Nutrition information usage, in this respect, should be assessed carefully and in a valid way as it has been put forward that merely distinguishing between 'users' and non-users' is too simplistic for any meaningful conclusions (Wahlich et al., 2013).

Research questions and hypotheses

In this research, we use data from an online process-tracing study in which we measured the actual usage of available nutrition information during substitutive food choices made by adults who had the intention to eat healthily (Van Buul et al., 2017). From this data, we investigate if we can group participants that cluster on energy, salt, sugar, and saturated fat information used. We posit the following research question:

> *Are there distinct subgroups within the group of consumers who intend to eat healthily, segmented on the time and frequency of energy, salt, sugar, and saturated fat information usage, and what are differences in demographic variables, psychosocial variables, nutrition literacy scores, and taste preferences between these groups?*

Considering that there has been evidence of a positive effect of nutrition information usage on healthy choices in the general population, we hypothesize that a cluster of consumers who intend to eat healthily, who can be segmented on high usage of nutrition information, will make significantly more healthy food choices (**H1**).

Using the HAPA model as guidance, we hypothesize that there is a significant difference in the level of intention, action planning and/or self-efficacy between clusters of consumers who intend to eat healthily, segmented on their usage of nutrition information. We expect that a segment of consumers who use more nutrition

information will have also a higher level of intention to eat healthily, engage in more planning, and are more self-efficacious about their food choices (**H2**).

To increase explanatory power, we broaden our scope and include two more predictors that theoretically could be of relevance. We posit that there is a significant difference in the level of nutrition literacy scores and/or taste preferences between clusters of consumers who intend to eat healthily, segmented on their usage of nutrition information (**H3**).

MATERIALS AND METHODS

Study design and participants

As introduced, we conducted an online process tracing study and survey for an earlier study (Van Buul et al., 2017). In this study, Dutch-speaking consumers who intend to eat healthily were asked to fill in an online questionnaire on their psychosocial and demographic characteristics, intentions to eat healthily, and their food choice behavior in July 2016. Participants were recruited through an online panel (http://academicresearchpanel.com/). A random subset of members of this panel were invited through e-mail to participate in the study. This introductory e-mail included a link to a page that outlined the broad purpose of the study and information about inclusion criteria (i.e., >17 years of age, intending to eat healthily in the coming period, and using a computer with a mouse (no touch screen)). Informed consent was acquired by prompting participants to check boxes behind four statements, agreeing that they understood the purpose of the study, were informed about the inclusion criteria, understood that collected data was not linked to personal information, and were free to drop out at any time without giving a reason. In total, 240 participants complied with the inclusion criteria, provided informed consent, and completed the full set of questions and tasks in the online research. From all participants, 148 were female (61.7%). The mean age was 51.65 years (±13.72 (S.D.)), the mean body mass index was 25.42 (± 4.03 (S.D.)).

Measurement of variables

As also detailed in our earlier work (Van Buul et al., 2017), we developed an online questionnaire in Dutch in which we included items for all typical constructs from the HAPA model: intention, self-efficacy, action planning, and coping planning. The questionnaire items were answered by (dis)agreeing to statements on a 7-point scale ranging from completely disagree (1) to completely agree (7). The intention to eat healthily construct was measured by translating and adapting items from Schwarzer and Renner (2000), e.g., 'I intend to eat healthful foods over the next months'. The self-efficacy construct was also measured by adapted items from Schwarzer and Renner

(2000), e.g., 'I can manage to stick to healthful food even if I have limited time'. Action planning and coping planning were measured by translating and combining items based on the ones used in a variety of HAPA related studies (Luszczynska et al., 2007; Schwarzer et al., 2007; Sniehotta et al., 2006), e.g., 'I have a detailed plan how to respond when someone offers an unhealthy snack'. Furthermore, we asked participants about their demographic status and included items on psychosocial factors.

Using the Nutrition Literacy Scale (NLS), we measured nutrition literacy in our participants (Diamond, 2007; Nguyen et al., 2015). This NLS consists of a sequence of statements in which a part of a sentence is left blank (e.g., 'Calcium is ____ for bone health'. Participants are presented four options (e.g., 'essential', 'osteoporosis', 'expensive', 'prescription') and asked to pick the one that makes the most sense to them to complete the statement. We translated and slightly adapted the items to fit the Dutch situation (e.g., ounces to grams). Six of the original twenty-eight items were not included because of a poor fit to the nutrition literacy construct for our study (e.g., questions related to the price of healthy foods and weed-control techniques of organic foods).

After making their initial food choices, participants were asked to again choose between the products presented earlier. This time, they did not have the make the option to view additional attributes. This time, their decision should be solely based on taste. We coded these "taste preference scores" as '1' when they had a taste preference for the unhealthy option, as '2' when they indicated not to have a preference for both options, and '3' when they had a taste preference for the healthy option. The recorded values per choice were aggregated into a continuous variable ranging from a general taste preference for the unhealthy option (9), to a general taste preference for the healthy option (27).

Measurement of nutritional information considered

Using a 2007 computer-based experiment on food choices as a basis (Scheibehenne et al., 2007), we used an open source program to quantify food choice behavior (MouselabWeb 1.00 beta (Willemsen & Johnson, 2011)). Like another computer-based experiment using pictures of canteen lunches (Schulte-Mecklenbeck et al., 2013), we investigated what nutrition information was utilized to make choices. In our study, also reported in our earlier work (Van Buul et al., 2017), we prompted participants to choose common food products that are found in supermarkets. They had to choose between nine different pairs of very similar products. Of each product, the name and picture were shown and participants had the possibility to view eight more attributes in a matrix form, similar to the design of food labels. Participants were asked which of the two products they would purchase for a price acceptable to them and were instructed not to base their decisions on taste (see Figure 7).

At the beginning of each choice, all pieces of nutrition information on product attributes were not visible to the participant (i.e., energy, fat content, protein content, etc.). The picture and the name of the product were visible. Participants could make information visible by opening a cell, by moving the cursor over it; the cell closed when the cursor was moved away. Using the MouselabWeb software, both the frequency and time of opened cells were tracked and stored on the university server on which the online questionnaire was hosted.

Figure 7: A screenshot of a choice matrix provided in MouselabWeb, as also used in our earlier research (Van Buul et al., 2017).

The matrix consisted of two columns, each representing one food product. Each column displayed the product's name, its image, and eight nutritional attributes (ingredient declaration, energy, total carbohydrates, sugars, total fat, saturated fat, protein, and salt). The position of the foods in the columns (left/right) was randomized between

choices and participants. The closed attributes were also counterbalanced in terms of the row in which they appeared, but remained linked with the appropriate column (product). Participants read detailed instructions about how to use MouselabWeb and conducted a guided practice trial before starting with the substitutive food choice tasks (Schulte-Mecklenbeck et al., 2013).

Only when participants opened a cell for more than 100ms, we included the data in our analysis on nutrition information considered. Based on literature, we expected acquisitions <100ms not to be read and comprehended by the participants (M. A. Just & Carpenter, 1980). Likely, such data points were the result of involuntary or accidental openings when scrolling over the page. Additionally, like our earlier research (Van Buul et al., 2017), we excluded the choices that participants made for products that they were allergic to, or had a medical condition prohibiting consumption. These choices were not counted towards their score of healthy choices made.

The 9 food choices were picked from the website of the Dutch Centre for Nutrition (Voedingscentrum, 2016), see Table 12. This institute uses the so-called Wheel of Five (Dutch: De Schijf van Vijf), a food products-healthy choices information graphic, to give straightforward nutrition advice. On the institute's website, food choice recommendations are provided. The 9 choices that we used were all listed on the website as examples of what foods can be easily substituted with a similar product (e.g., using olive oil instead of coconut oil for cooking).

Table 12: The 18 comparable food products (9 dichotomous choices) presented to participants, as presented earlier in Van Buul et al. (2017).

Choice:	Unhealthy choice*:	Healthy choice*:
1	Gouda Cheese 48+**	Gouda Cheese 30+**
2	Coconut oil	Olive oil
3	Spelt bread (refined)	Whole-wheat bread
4	Canned string beans (with added salt)	Frozen string beans
5	Culinary pork loin (injected with water and additives)	Pork loin
6	Calvé Peanut butter (with more fat and salt)	100% Peanut butter
7	Santa Maria Extra Fine Selection Thai Red Curry (with added salt)	Original Spices by Jonnie Boer Thai Red Curry
8	Salted full-cream butter	Liquid baking fat (from vegetable oils)
9	Feta 45+	Goat cheese 45+

* Participants saw Dutch names and a picture without information between brackets
** The numbers indicate the fat content of the cheese, based on the percentage of milkfat solids – a common way of indicating cheese differences in the Netherlands.

STATISTICAL ANALYSES

All analysis were conducted using the IBM SPSS Statistics software version 22. Participants who did not complete the full study were excluded from the analyses. In order to generate groups of consumers based on their nutritional information usage, a cluster analysis was conducted. The variables used for classification included the total frequency and total time of energy, salt, sugar, and saturated fat considered. These variables were standardized into z-scores. The analysis was conducted in two steps, using a combination of hierarchical and non-hierarchical clustering approaches, as commonly used in studying food choices (Gorton, Ness, & White, 2013). This approach allows to form clusters with high internal and external homogeneities (Hair & Black, 2000).

Since hierarchical cluster analyses are sensitive to outliers, univariate outliers on the overall intention to eat healthily score (>1.5 interquartile range; n = 3) and multivariate outliers on the combined time and frequency of the 4 nutrition information summary scores (Mahalanobis Distance > 26.23, $p < 0.001$, n = 7) were removed from the dataset. This resulted in a total sample of 230 participants for the hierarchical cluster analysis. This was conducted using Ward's method based on squared Euclidian distances. As such, in every step of the clustering process, two clusters are merged such that the squared Euclidean distance between each respondent and the center of the cluster to which s/he belongs is minimized. The extracted initial cluster centers were saved and used as non-random starting points in an iterative k-means clustering procedure (Clatworthy, Hankins, Buick, Weinman, & Horne, 2007). The agglomeration schedule was calculated, and the inverse scree plots of Ward total within-group sums of squared errors of successive cluster solutions were constructed to determine the optimum numbers of clusters (= 3).

To examine the stability of the cluster solutions, we used a double-split cross-validation procedure (Friederichs, Bolman, Oenema, & Lechner, 2015; Vansteenkiste, Sierens, Soenens, Luyckx, & Lens, 2009). Following this procedure, the sample was randomly split into halves (subsample A and B) and the two-step cluster procedure was applied to each half. After that, the participants of subsample A were assigned to new clusters using an iterative k-means cluster procedure based on the cluster centers of subsample B and vice versa. The new cluster solutions were then compared for agreement using Cohen's kappa, to check if the two different approaches resulted in similar clustering solutions. There was very high similarity (κ > 0.972). The cluster centers from subsample A had a slightly higher similarity, hence they were used create the definitive cluster solution in the combined dataset.

For the post-hoc tests following significant outcome of ANOVA analyses, either Bonferroni or Games-Howell tests were done based on the results of the test of homogeneity of variances. For the multinomial logistic regression, multi-collinearity problems were ruled out by consulting the Variance Inflation Factor (= 1.926). The

assumption of proportional odds was met, as assessed by a full likelihood ratio test comparing the fit of the proportional odds model to a model with varying location parameters, χ2 (136) = 73.839, p = 1.000. For the multinomial logistic regression, statistical power was assessed based on a binary logistic regression model. This is because the multinomial logistic regression in essence is conducted using a series of binary logistic regressions. Combined, the two clusters with the lowest number of participants (1 & 3; n = 136) are well above the recommended minimum of 10 participants per independent variable (= 7) in the model to achieve empirical validity (Hosmer Jr, Lemeshow, & Sturdivant, 2013).

RESULTS

Three clusters were formed from the group of participants. The clusters were based on the usage of energy, salt, sugar, and saturated fat information in making 9 dichotomous food choices presented in Table 12. In Table 13, the clusters are presented, as well as the mean values (± S.D.) of the variables that were used for cluster formation. One-way ANOVAs were conducted to determine per variable if there were significant differences between clusters. Post-hoc tests were done when significant difference were found. We have named the clusters according to the level of nutrition information used (high, medium, and low).

Table 13: Differences between clusters on usage of energy, salt, sugar, and saturated fat information considered (both total time and frequency)

	Cluster 1 *High information users*	Cluster 2 *Medium information users*	Cluster 3 *Low information users*	Total	
	n = 82	n = 86	n = 54	n = 222	F (df = 2)
Total freq. energy	30.59 ± 5.60^a	23.13 ± 5.56^b	8.93 ± 5.22^c	22.43 ± 9.97	254.28***
Total time energy (s)	27.14 ± 6.17^a	17.51 ± 5.24^b	6.20 ± 3.82^c	18.32 ± 9.64	254.42***
Total freq. salt	30.01 ± 5.63^a	20.34 ± 4.89^b	8.70 ± 5.54^c	21.08 ± 9.77	261.14***
Total time salt (s)	25.27 ± 6.11^a	13.86 ± 4.15^b	5.77 ± 4.39^c	16.11 ± 9.17	260.41***
Total freq. sugar	28.15 ± 4.91^a	21.24 ± 4.50^b	7.54 ± 4.25^c	20.46 ± 9.16	329.42***
Total time sugar (s)	23.46 ± 6.39^a	14.23 ± 4.22^b	5.09 ± 3.57^c	15.42 ± 8.69	222.69***
Total freq. sat. fat	30.39 ± 5.25^a	22.23 ± 5.34^b	8.26 ± 4.38^c	21.85 ± 9.90	307.98***
Total time sat. fat (s)	28.23 ± 7.15^a	17.89 ± 4.99^b	6.07 ± 4.27^c	18.83 ± 10.27	244.14***

All values are all mean ± S.D.; For each variable, means with different superscript indicate a significant difference at P < 0.05 using Bonferroni or Games-Howell post-hoc tests
*** p < 0.001

Differences between clusters

In line with our overall research question, we compared the three clusters on demographic, psychosocial, and other relevant variables. As can be seen in Table 14, the *Low information users* made on average significantly less healthy choices that those from the other two clusters. Through a Spearman's test, we also observed that there is a strong positive correlation between cluster allocation (high vs. low) and healthy choices $r_s(220) = 0.451$, $p < 0.005$. The *High information users* were on average significantly older than the other clusters.

Interestingly, the three clusters also significantly differed on usage of information on carbohydrates, protein, ingredient declaration, and total fat content – all other available information they could consult. Apparently, within our studied health-conscious consumers, there was a high variability in the quantity of information considered, but not what information considered. In all instances, the *medium information users* used significantly less information than the *high information users* and more information than the *low information users*.

We observed no significant ($p < 0.05$) univariate differences between clusters on intention to eat healthily, action planning, coping planning, and self-efficacy measures. For intention to eat healthily, action planning, and coping planning, however, there appears to be some directional difference between groups at $p < 0.10$. Especially the *low information users* appear to score slightly lower on these psychosocial variables than the other two groups.

Partially in line with our third hypothesis, there is a significant difference in the taste preferences between clusters. The *high information users* had a significantly higher general taste preference for the healthy options presented. Unfortunately, we could not confirm that there is a significant difference between clusters on nutrition literacy scores. Again, there does appear to be some directional effect at $p < 0.10$ in which the *low information users* appear to score slightly lower on a nutrition literacy test than the other two groups.

Furthermore, in line with our expectations, we observed a difference on perceived importance of attributes between clusters. The attributes we used for cluster formation (the four 'evils') were significantly differently perceived as being important in making healthy choices in the three clusters. In general, the *high information users* perceived energy, total sugar, total fat, total saturated fat, and salt information to be more important in making healthy choices than the *low information users*.

Table 14: Means of demographic information, other nutrition information usage, and psychosocial variables per cluster

	Cluster 1 High information users	Cluster 2 Medium information users	Cluster 3 Low information users	Total	F / χ2 (df = 2)
Food choice behavior:					
% healthy choices	88.95 ± 12.27[a]	84.2 ± 15.39[a]	67.17 ± 18.32[b]	81.81 ± 17.33	35.48***
Demographics:					
Age	54.96 ± 12.68[a]	48.93 ± 13.81[b]	49.72 ± 13.62[b]	51.35 ± 13.58	4.81**
BMI	26.10 ± 4.50	25.32 ± 3.79	24.85 ± 3.86	25.49 ± 4.09	1.67
% female	56.1%	67.4%	63.0%	62.2%	2.32
Nutrition information:					
Total freq. carbs	28.91 ± 5.22[a]	21.13 ± 5.50[b]	8.54 ± 5.92[c]	20.94 ± 9.55	222.99***
Total time carbs (s)	27.23 ± 9.52[a]	15.74 ± 5.95[b]	6.16 ± 5.15[c]	17.65 ± 11.00	139.49***
Total freq. protein	27.93 ± 5.60[a]	21.28 ± 5.96[b]	7.89 ± 4.58[c]	20.48 ± 9.47	216.22***
Total time protein (s)	24.85 ± 6.82[a]	16.77 ± 9.24[b]	5.14 ± 3.71[c]	16.93 ± 10.51	117.90***
Total freq. ingredients.	32.24 ± 8.08[a]	24.70 ± 7.37[b]	10.52 ± 7.11[c]	24.04 ± 11.26	134.23***
Total time ingredients (s)	49.48 ± 28.26[a]	29.47 ± 15.20[b]	12.82 ± 12.38[c]	32.81 ± 24.97	53.70***
Total freq. tot. fat	28.68 ± 5.27[a]	21.08 ± 6.00[b]	8.26 ± 5.40[c]	20.77 ± 9.62	216.98***
Total time tot. fat (s)	27.02 ± 7.44[a]	15.85 ± 5.60[b]	6.76 ± 6.48[c]	17.76 ± 10.26	162.04***
Psychosocial:					
Intention to eat healthily	5.64 ± 0.85	5.66 ± 0.81	5.37 ± 0.88	5.58 ± 0.85	2.33†
Action planning	4.05 ± 1.55	4.03 ± 1.49	3.51 ± 1.64	3.91 ± 1.56	2.45†
Coping planning	4.12 ± 1.54	3.92 ± 1.54	3.49 ± 1.72	3.89 ± 1.60	2.54†
Self-efficacy	5.18 ± 1.06	5.19 ± 1.06	5.25 ± 1.07	5.20 ± 1.06	0.80
Other:					
Score on NLS‡	18.93 ± 2.04	18.76 ± 2.19	18.04 ± 2.89	18.64 ± 2.34	2.55†
Taste preference	20.49 ± 2.35[a]	19.57 ± 2.56[b]	19.09 ± 2.53[b]	19.79 ± 2.53	5.74**
Physical activity	4.32 ± 2.09	4.16 ±2.05	4.25 ± 2.01	4.24 ± 2.05	0.12
% allergic	14.6%	12.8%	14.8%	14.0%	0.16
% on diet	28.0%	31.4%	25.9%	28.8%	5.81
% tertiary education	74.3%	77.7%	78.4%	76.7%	11.98
Perceived importance of attributes:					
Ingredients	4.11 ± 0.72	4.06 ± 0.80	3.85 ± 1.05	4.03 ± 0.85	1.62
Energy	3.90 ± 0.88[a]	3.65 ± 0.98[ab]	3.46 ± 1.19[b]	3.70 ± 1.01	3.28*
Carbohydrates	3.71 ± 0.94	3.74 ± 0.80	3.41 ± 1.09	3.65 ± 0.93	2.45†
Total sugar	4.37 ± 0.73[ab]	4.47 ± 0.68[a]	4.06 ± 0.92[b]	4.33 ± 0.78	4.95**
Total fat	4.04 ± 0.92[a]	3.94 ± 0.87[ab]	3.59 ± 1.14[b]	3.89 ± 0.97	3.66*
Saturated fat	4.37 ± 0.76[a]	4.22 ± 0.69[a]	3.61 ± 1.12[b]	4.13 ± 0.89	14.02***
Protein	3.70 ± 0.87	3.69 ± 0.87	3.35 ± 1.01	3.61 ± 0.91	2.85†
Salt	4.45 ± 0.71[a]	4.29 ± 0.73[a]	3.87 ± 0.93[b]	4.25 ± 0.81	9.32***

All values are all mean ± S.D.; For each variable, means with different superscript indicate a significant difference at P < 0.05 using Bonferroni or Games-Howell post-hoc tests

‡ NLS = Nutrition Literacy Scale; † p < 0.1; * p < 0.05; ** p < 0.01; *** p < 0.001

Multinomial Logistic Regression

Although there were no significant differences (p < 0.05) between the psychosocial variables listed above using an ANOVA, there is some apparent directional difference in cluster allocation. In line with our hypotheses, we would like to understand better how these variables contributed to cluster allocation, and thus the amount of information on the four 'evils' considered. To this end, we performed a multinomial logistics regression. In making this model, we included intention to eat healthily, action planning, coping planning and self-efficacy as covariates to predict if participants were low-, medium-, or high-information users. To correct for the (significant) difference in age, taste preferences, and scores on the NLS between the cluster 1 and cluster 2 and 3, we included these variables too in our model.

The deviance goodness-of-fit test indicated that the model was a good fit to the observed data, $\chi2(428) = 437.825$, $p = 0.361$, as did the Pearson goodness-of-fit test, $\chi2(428) = 447.107$, $p = 0.253$. These results should be treated with some caution, however, as there were a very large number of covariate patterns (= 230) and 66.7% of cells had zero frequencies. A better method of assessing model fit is to look at the change in model fit when comparing the full model to the intercept-only model. The difference in the -2 log likelihood between these two models has a $\chi2$ distributed with degrees of freedom equal to the difference in the number of parameters. To this end, we can conclude that the model statistically significantly predicted cluster allocation over and above the intercept-only model, $\chi2(14) = 41.304$, $p < 0.001$.

In Table 15, the results of the multinomial logistic regression are displayed.

Table 15: The effect of age, intention to eat healthily, action planning, coping planning, and self-efficacy, score on NLS, and taste preferences on cluster allocation, with *low information users* as reference cluster

			95% Wald Confidence Interval			
Cluster	Variable	Odds ratio	Lower limit	Upper limit	B	p-value
High information users	Age	1.030	1.001	1.060	0.030	0.041*
	Intention to eat healthily	1.889	1.008	3.540	0.636	0.047*
	Action planning	1.044	0.699	1.559	0.043	0.833
	Coping planning	1.388	0.928	2.076	0.328	0.111
	Self-efficacy	0.404	0.233	0.700	-0.907	0.001**
	Score on NLS	1.139	0.967	1.343	0.130	0.120
	Taste preference	1.263	1.079	1.479	0.234	0.004**
Medium information users	Age	0.996	0.971	1.022	-0.004	0.774
	Intention to eat healthily	1.880	1.030	3.430	0.631	0.040*
	Action planning	1.196	0.813	1.760	0.179	0.363
	Coping planning	1.100	0.757	1.599	0.095	0.618
	Self-efficacy	0.475	0.280	0.803	-0.745	0.005**
	Score on NLS	1.119	0.955	1.312	0.113	0.164
	Taste preference	1.079	0.932	1.250	0.076	0.309

All values are using the *low information users* as reference cluster. * p < 0.05; ** p < 0.01; *** p < 0.001

We observe that both intention to eat healthily and self-efficacy now appear significant predictors of cluster allocation in this model – which was not apparent from the initial ANOVA (Table 14). Again, we see that age and taste preference are significant predictors of cluster allocation when comparing *high information users* to *low information users*. Apparently, those who are older and those who prefer healthier products purely on taste are more likely to consult more nutrition information.

The fact that both intention to eat healthily and self-efficacy now appear significant predictors is remarkable. Taking into account the beta values of these two variables, a relatively low intention to eat healthily combined with a relatively high self-efficacy would predict allocation to the *low information users* cluster. This particular group of consumers are less highly committed to eating healthily, but simultaneously they are more highly confident in their own ability to make healthy choices.

DISCUSSION

As introduced, we set out to investigate clusters of consumers who intend to eat healthily and the possible behavioral, demographic and psychosocial differences between clusters, segmented on the time and frequency of energy, salt, sugar, and saturated fat information usage when making food choices. As expected, these consumers prove to be a heterogeneous group in which there are large differences in terms of information use and subsequent food choice behavior. Between clusters, we observed a 21.78 percentage point difference (88.95% minus 67.17%) in how often the healthy option was chosen out of two substitutable food products. With an estimated 200 food decisions per day (Wansink & Sobal, 2007), over 43 choices could have resulted in the healthy option if only for cluster allocation.

Important univariate differences between clusters are age and taste-preferences. Although the higher age could be indicative of a worse memory in this group – resulting in going back to more cells repeatedly – the difference in mean age was relatively limited (~6 years, see Table 14). The percentage of healthy choices is lower only in the *low information users* cluster. Where *high-information users* had a significantly higher taste preference for the healthy products compared to *low-information users*, there could be some reverse causality. There is evidence that knowing the healthiness of a product could influence perceived tastiness (Werle, Trendel, & Ardito, 2013), which may explain our findings.

More interesting from a public-health perspective is our finding that there is a unique combination of intention to eat healthily and self-efficacy that could predict cluster allocation. Participants in the *low information users* cluster have a relatively low intention to eat healthily combined with a relatively high self-efficacy. Our data shows that belonging to this group is associated with significantly more unhealthy food choices. If these results are confirmed in future studies, health interventions might

need to focus on avoiding overconfidence in making food decisions. This would facilitate that, even when ones intention to eat healthily is (temporarily) low, consumers will make an effort to consult necessary nutrition information prior to making a food choice.

While we agree that improving nutrition literacy is an important target for public health interventions, our present study shows that the effect on nutrition information usage is limited. As expected, nutrition information usage in intricate food choices is a complex behavior and is dependent on more than improving nutrition literacy alone. In public health campaigns, we therefore recommend that both nutrition literacy and nutrition information usage in general should be targeted to ensure optimal results in terms of healthy food choices. Perhaps consumers should not become over-confident in their ability to make the right choices.

Intention to eat healthily x self-efficacy

In recent years, many studies have adopted the HAPA model to explain and predict risk-reducing behaviors (e.g., vaccination (Ernsting, Knoll, Schneider, & Schwarzer, 2015) and health-enhancing behaviors (e.g., physical activity (Lippke & Plotnikoff, 2014)). Given its apparent nice fit to food choice behavior, an increasing number of studies has focused specifically on the context of healthy eating (Godinho et al., 2013; Lange et al., 2013; Radtke et al., 2014; Richert et al., 2010). In our study, we find evidence of its applicability to predicting healthy behavior in terms of nutrition information usage. Moreover, we underscore the importance of using multivariate models to understand health behavior.

Between clusters, there is no significant difference on single psychosocial factors mentioned in the HAPA-model ($p < 0.05$). Although there are some directional differences ($p < 0.1$), we have no hard evidence to state the importance of one single psychosocial factor on promoting information usage, and thus cluster allocation. In a more in-depth analysis, using a multinomial logistical regression, there appears to be an interplay between two variables in which the combination of high intention and low self-efficacy has a positive effect on information usage. Like the original HAPA-model, results indicate that motivational and volitional constructs need to be combined to predict an individual's health behavior.

To investigate the precise interaction between intention and self-efficacy, we added an interaction variable (intention x self-efficacy) to the multinomial logistics regression model (not presented in the table), but this proved not significant ($p > 0.622$). We then replaced intention to eat healthily with a standardized residual variable that takes into account merely the variance, which cannot be explained by both intention to eat healthily and self-efficacy. After computing it using a linear regression of the effect of self-efficacy on intention to eat healthily ($\beta = 0.651$), we found that self-efficacy became a non-significant predictor in the model ($p = 0.106$). Although we were unable to draw new conclusions from these analyses, they do signal that there is some unaccounted

variance that could explain the insignificance of the interaction variable. In future studies, we therefore aim to increase the detail of our measure of a participant's confidence in making healthy food choices. This could help to better understand the phenomenon that there might be a limit to the effect of self-efficacy on the healthiness of food choices (Hartmann, Dohle, & Siegrist, 2015; Huntsinger & Luecken, 2004).

Methodological limitations

While the present study has several strengths, particularly the use of process tracing software to find out the use of nutrition information in food choices and focus on the underrepresented consumers who intend to eat healthily (as opposed to the general population), it also has some limitations. First, it should be noted that the design is cross-sectional. Therefore, it is not possible to infer causal relationships from the results, nor does it give information on long-term outcomes related to the food choices and the process that precedes making the choices (Berkman, 2017). Second, the demographic characteristics of participants in our study are not completely in line with the general Dutch population, as discussed in our earlier work (Van Buul et al., 2017). Our participants were considerably more educated and comprised more of women compared to the general Dutch population (Statline, 2016). The questionnaire was sent out to about 1000 email addresses in the panel – which consists of a cross-section of the general population according to the panel administrator. Third, most individuals generally do not make food choices on a computer yet (barring the growing number of online grocery shoppers). There is surging evidence, however, that differences between outcomes using an online convenience sample as compared to laboratory-based off-line research are limited in social psychology research (Casler et al., 2013; Riva et al., 2003). Lastly, we consider self-selection as a potential limitation of our study. Although our participants indicated to have an intention to eat healthily, and we have confirmed it through our questionnaire, there might be an underrepresentation of participants who also intend to eat healthily, but are less expressive of that fact.

In our cluster analysis, we decided to focus only on salt, sugar, saturated fat, and energy information used by participants. As introduced, there is strong evidence that excessive intake of foods high in these four 'evils' are a public health problem. One could argue that we could have clustered on all nutrition information considered. Given the high and significant differences between clusters on all other nutrition information (carbohydrates, protein, ingredient declaration, total fat), however, our results will likely not change significantly. It is also this correlation that barred us from clustering on differences between what information was considered, rather than the overall amount that is considered. It would be interesting to disentangle those consumers who focus only on salt, for instance, from those who focus only on sugar. Our current methodology, however, did not allow such cluster formation.

In this light, it is also interesting to consider those participants who used only extremely limited nutrition information in our experiment. As the name and picture of the product were always visible, those participants might obtain a high degree of information from these pieces of information alone. In a future study, it would be worthwhile to understand how participants can draw nutrition information from pictures and product names. In this respect, the literature on heuristics provides evidence of a 'less is more' effect in nutrition information (Scheibehenne et al., 2007; Schulte-Mecklenbeck et al., 2013; Wansink et al., 2009). The attenuating role of self-efficacy in our study provides avenue for further study in this field.

RECOMMENDATIONS AND CONCLUSION

By using data from our online process tracing study, we were able to unravel the heterogeneity of consumers intending to eat healthily who make substitutive food choices. We find that within this group there are clusters of consumers who are often choosing unhealthy foods, perhaps even without knowing it themselves. As hypothesized, when clustered on the time and frequency of energy, salt, sugar, and saturated fat information usage, we find a significant difference between healthy food choice behaviors between clusters (**H1**).

Through our in-depth analysis, we found some evidence that there is an interplay between motivational and volitional constructs in predicting cluster allocation, particularly intention to eat healthily and self-efficacy, partially confirming **H2**. Although our results are not conclusive, they could indicate a shift in focus for public health interventions. Especially when this interplay between intention and self-efficacy can be confirmed in non-health-conscious consumers. For this, we recommend to replicate our study in a different population. In such a study, an improved measure for self-efficacy should be used to understand better the unaccounted variance in our model.

In our previous study (Van Buul et al., 2017), we argue that models based on motivational and volitional constructs should be augmented to improve predictive power. We find, for instance, that nutrition literacy is an important predictor of the percentage of healthy choices made. Through the cluster analysis in this study, we confirm taste preferences play an important role in understanding healthy food choices (**H3**). Nutrition literacy, however, only has limited effect on nutrition information usage, and thus cluster allocation.

Our study shows that consumers who intend to eat healthily cannot be seen as a single entity, and should not be advised as such by public health interventionist who are targeting this important group. Rather, communication and guidance personal approach is required at a personal level. There are tremendous differences within this group in terms of use of nutrition information and subsequent food choices. We recommend

that these differences should be taken into account in the development of innovative, evidence-based, policies and interventions to better promote healthier food choices.

Chapter 6

General discussion

Food for thought

The main aim of the present research was to identify how nutrition information affects food choices, with a focus on providing an interdisciplinary approach into the factors that attribute to the misfit between healthy diet intentions and behavior. In particular, through narrative reviews of the scientific literature, the perception of nutrition and health claims on functional foods, and misconceptions related to fructose-consumption were studied. In addition, through an empirical process tracing study, determinants of substitutive food choices from (groups of) consumers who have the intention to eat healthily were investigated.

   This final chapter provides a summary and integration of all the (main) findings of the studies presented in the preceding chapters, and relates these findings to the results of previously conducted research. Furthermore, practical and methodological considerations are discussed and recommendations for future studies and practice are presented.

   The research in this thesis was split in two parts. In **Chapter 2** and **Chapter 3**, it is discussed how food choices may be biased by health-related outcome expectancies of nutrients/ingredients in food. In this first part of the dissertation, we posited that these outcome expectancies can be formed through food marketing and public health professionals, among other sources. We found that nutrition information related to specific nutrients and foods may affect a consumer's purchase intentions through different outcome expectancies. In **Chapter 4** and **Chapter 5**, it is discussed how well a prevailing intention to eat healthily is translated into behavior, building further on the conceptual model provided in the introduction. This second part addresses why behavior can still not be in line with intentions, with a focus on nutrition literacy and nutrition information usage. First, the findings from the two parts are discussed separately, before stressing the overall role of planning, self-efficacy, and nutrition literacy across the research presented in this dissertation.

PART 1: OUTCOME EXPECTANCIES AND FOOD CHOICES

As introduced in this dissertation, food choices are not determined solely by physiological needs (i.e., hunger or thirst). They are dependent on many more factors, including consumer perception of how a food may influence his or her health. Especially choices for functional foods, which are developed with health-promotion or disease prevention in mind, in part, are dependent on how consumers perceive the health outcomes of consuming them (Bornkessel et al., 2014). But also choices for staple foods, such as wheat-based products with fructose-containing sugars, are affected by consumer expectations about their healthiness (Borra & Bouchoux, 2009), which in turn

is influenced strongly by social media and perceptions within family and friends (Liu & Lopez, 2016).

In the first part of this thesis, we aimed to further study the effect of these outcome expectancies on food choices. In **Chapter 2**, this was done by conceptualizing how nutrition and health claims on functional foods contribute to a consumer's expectancy of reaching their health goals. In this study, the prevailing European regulations on nutrition and health claims were reviewed. These regulations form the framework of many functional food concepts, which were developed specifically for consumers to reach health goals easier. We discussed that these functional foods are often not a market success, driven by the inability to appropriately frame the health outcome of consuming the functional food and by the consumers' preference for short-term satisfaction rather than long-term benefits. In light of this, following their systematic review of the recent research on the effect of health-related claims on food choices, A. Kaur, Scarborough, and Rayner (2017) underlined that the effect of nutrition and health claims on dietary choices warrants further study and conceptualization. They argued that most research is conducted in artificial settings, and further research is needed to assess effects of claims in real-world settings, calling for more field-studies that are scalable from experiments in a lab setting.

In our research, we categorized research streams that address how nutrition and health claims on functional foods may contribute to a consumer's expectancy of reaching their health goals. We argued that if consumers *need the product, accept the ingredient, understand the benefit, and trust the brand,* they are more likely to expect functional foods to help them in reaching overall health goals. It provided a very clear example of how outcome expectancies can affect food choices.

To illustrate further the underlying complexity of how outcome expectancies affect food choices, we focused on a specific outcome (obesity) of consuming foods with a specific component (fructose-containing sugars) in **Chapter 3**. By concretizing, we exemplified that there are many misconceptions about health effects of nutrients. These misconceptions may result in incorrect outcome expectancies and hinder consumers to make healthy food choices. Through a narrative review, we evaluated the evidence regarding effects of foods with fructose-containing sugars on obesity. Taking into account the available evidence, we found that excessive doses of foods with fructose-containing sugars can have a clear negative effect on obesity. When consumed in moderate amounts, however, we found there appears to be no specific negative effect of fructose-containing sugars on obesity. On the contrary, we found that consumption of moderate amounts appeared to be associated with reduced risk of overweight and diabetes. Accordingly, we argued that consumers should not blindly follow (social) media messages regarding unsubstantiated effects of fructose. These messages can influence their outcome expectancies of consuming products with fructose-containing sugars. We concluded that public health strategies should be implemented to provide consumers with the appropriate information to make food

choices based on validated outcomes, to avoid misconceptions in outcome expectancies.

In both chapters, we also addressed how food consumption decisions were steered by outcome expectancies. Our findings confirm earlier conclusions on how consumer beliefs about a product's healthiness are affecting decision behavior (McFerran & Mukhopadhyay, 2013; Rozin, Ashmore, & Markwith, 1996). In a study by Lawrence et al. (2011), for example, the effect of overall outcome expectancies on a healthy diet in woman were combined with other psychosocial variables to explore this relationship in depth. In their paper, evidence is provided for a strong effect of outcome expectancies on the quality of diet in women with a low educational background. The researchers hypothesized, and confirmed, that women with a lower educational attainment have more ambiguous beliefs about the benefits of healthy eating. In woman with a higher educational background, there appeared to be less effect of outcome expectancies on dietary choices. They did find that the group with the higher educational background had more positive outcome expectancies and food involvement and lower negative outcome expectancies about their food choices.

This underlines our hypothesis that nutrition knowledge and demographic factors play an important role in the relation between outcome expectancies and food choices. In a recent study that aimed to predict sugar consumption using a dual-process theory derived model, it was further elucidated that beliefs about outcomes affected both deliberate and impulsive food choices. Moreover, as stressed in the HAPA and other social cognition models (Conner & Norman, 2015; Schwarzer, 1992), outcome expectancies are interlinked with self-efficacy. In making choices related to health-related goals, consumers usually unite their confidence in their own ability to achieve the intended outcome with the expected outcome based on their actions. In other words, to make healthy food choices, it is likely that consumers need to know what is healthy and what is not, and that they need to be confident enough to believe that they are right and they can perform the behavior (Luszczynska et al., 2007; McFerran & Mukhopadhyay, 2013; Moores & Chang, 2009; Rozin et al., 1996).

PART 2: NUTRITION INFORMATION, PLANNING, AND THE INTENTION-BEHAVIOR GAP

In **Chapter 4** and **Chapter 5** of this thesis, we have presented research in which participants who had the intention to eat healthily were asked to choose nine times between a set of two comparable foods. We aimed to improve our understanding of why food choice behavior is not always in line with ones intentions, with a focus on nutrition literacy and nutrition information usage. During these nine dichotomous food choices, participants had the option to consider pieces of nutrition information, and we carefully measured the actual usage of this available nutrition information. Using

process tracing software, we measured the frequency and time of nutritional information considered. Combined with demographic and psychosocial data obtained from the same individuals, we were able to study determinants of inadvertent unhealthy substitutive food choices and differences between consumers.

In this research, we observed that, despite the increased aim to eat healthier, consumers often make choices that are not in line with their intention. We discussed that the fundamental idea behind this phenomenon is the intention-behavior gap (Sheeran, 2002). This intention-behavior gap tells us that some people may develop an intention to perform healthy behavior, but they do not take the appropriate actions. In this respect, we studied what factors are responsible for this part of the intention-behavior gap. With this information, health behavior change methods can be further improved. We take a different approach than research using dual process models, in which the study focuses on differences between intuitive and deliberative behavior (Chance et al., 2014; Scheibehenne et al., 2007). The aim of the studies in part 2 was to broaden the understanding of motivational and volitional processes involved in food choices, with a specific focus on the role and interplay of nutrition literacy and nutrition information usage in the intention-behavior group.

Action planning, coping planning and self-efficacy are common psychosocial factors found to influence how well intentions are translated into action (Schwarzer & Renner, 2000; Sniehotta, Schwarzer, et al., 2005). In our research, we further reviewed their role in the intention-behavior gap and augment these factors with a person's nutrition literacy and taste preferences to better explain the variance in food choice behavior. In the recent research using HAPA model to study food choice research (Godinho et al., 2013; Lange et al., 2013), it has already been suggested that taste preferences should also be included in models to better predict behavior. Other researchers have recently stressed the importance of nutrition literacy in behavioral models in general (Vaitkeviciute et al., 2015; Velardo, 2015). While intention, action planning and self-efficacy are considered to be important in predicting relatively simple food choice behavior (e.g., the amount of fruits/vegetables per day), we observed that the inclusion of nutrition literacy and taste preferences in the model were essential for the prediction of more complex behavior (e.g., choosing between feta cheese or goat cheese).

In part 2, we confirmed the importance of thoroughly reading available nutrition information to improve the healthiness of food choices in analyses of our online experiment. Our findings build further on existing food choice models, and can help decision makers in public health and food industry to understand better the complex process of food choices, especially in those consumers who already have an intention to eat healthily.

The observations made provide potential basis for intervention design to help consumers to minimize part of the intention-behavior gap; where there needs to be more focus on nutrition information usage and increasing nutrition literacy, for those who are intending to eat healthily. We argued that public health interventions that aim

to promote healthy food choices could be improved by including the importance of nutrition literacy and nutrition information usage to increase effectiveness. For example, its interventions could focus on improving attention to nutrition information, but also to improve comprehension by finding effective methods to display nutrition information. We also highlighted the strong heterogeneity between people in how well intentions are translated into behavior.

PLANNING IN FOOD CHOICES OF CONSUMERS WHO INTEND TO EAT HEALTHILY

By planning, a person develops a mental representation of a suitable future situation ("when" and "where") and a behavioral action ("how"). This was found to be effective for behaving towards a goal – such as healthy eating (Peters & Büchel, 2010; Sniehotta, Scholz, & Schwarzer, 2005). This planning will counteract our desire for immediate gratification, such as having an unhealthy snack, as found in a controlled experiment in which the effect of planning on impulsivity and energy intake was assessed (T. O. Daniel, Stanton, & Epstein, 2013). Also in studies utilizing the HAPA model, planning is found to be an important factor that influences how well intentions are translated into action (Luszczynska et al., 2007; Sniehotta, Scholz, et al., 2005).

In our research presented in **Chapter 4** and **Chapter 5**, however, we found only limited evidence that appropriate planning is an indicator of healthy food choices in participants intending to eat healthily. In Table 10 in **Chapter 4**, in which correlations between all main variables are listed, one can see that the planning constructs correlated with the self-efficacy construct. Moreover, they correlated with the time that participants used to consider various attributes prior to making a food choice. This multicollinearity could be the reason that they were not significant in the model – as the variance was captured by the correlating variables. Alternatively, in our study population of consumers who have a high intention to eat healthily, the variance in behavior appeared not to be dependent on the differences in action plans. In fact, this group was characterized by having a high level of planning (as can be seen in Table 6 in **Chapter 4**). It could be that, within the situation of having a high intention and being high in planning, it does not help to make even more detailed plans in this population. For them, it is much more important to increase nutrition literacy to steer healthy food choices.

SELF-EFFICACY AND NUTRITION INFORMATION USAGE IN FOOD CHOICES

Across the literature, we found that self-efficacy is a well-known indicator of healthy food choices (AbuSabha & Achterberg, 1997; de Vries, Dijkstra, & Kuhlman, 1988; Lawrence et al., 2011; Pearl & Lebowitz, 2014; Renner & Schwarzer, 2005; Schwarzer, 1992). In one particular study, the importance of self-efficacy on food choices was stressed using the HAPA model (Richert et al., 2010). In this longitudinal study in 411 German adults (331 of which were men), it was found that individuals with very low self-efficacy were not making healthy food choices, even when controlling for planning variables. Apparently, if a person lacks self-efficacy, even making detailed plans to make healthy choices does not seem sufficient to engage in appropriate behavior.

In this respect, self-efficacy appears to operate on two distinct stages in the conceptualization of moving from intention to behavior. From earlier studies using the HAPA model, it became clear that self-efficacy plays a very important role in the formation of intentions to eat healthily (Lange et al., 2013; Lippke et al., 2009; Luszczynska et al., 2007; Schwarzer, 2008; Schwarzer & Luszczynska, 2008). But also in those who already intend to eat healthily, ones actual healthy food choice behavior appears to be predicted by ones self-efficacy, according to a plethora of research (Lange et al., 2013; Lippke et al., 2009; Renner et al., 2008; Richert et al., 2010; Schwarzer & Renner, 2000). While we have not tested the first stage effect of self-efficacy on intention, we have found some evidence regarding the second-stage effect of self-efficacy on behavior (between intention and behavior). We found that self-efficacy could also have a negative effect on healthy food choice behavior in selected individuals. That is, we found some early evidence that consumers can have an intention to eat healthily, and a very strong belief that he or she will make the healthy choices, which could result in omitting to read nutrition information. Further research is needed to understand this double-edged sword effect of self-efficacy, in which more complex food choices might not benefit from an overly high self-efficacy – as people can become overconfident and omit to use nutrition information. We will discuss this further below, with respect to the measurement of self-efficacy.

We found early evidence that, for consumers with a positive intention to eat healthily, the confidence in a consumer's own abilities to engage in healthy behavior is an important but not essential prerequisite for healthy food choices. Interestingly, as set out in **Chapter 2**, one of the objectives of the European legislation on nutrition and health claims, was to increase this consumer confidence. We argue, however, that the legislation is not succeeding in this objective. In **Chapter 3**, we illustrated how this self-efficacy can be distorted due to seemingly competing messages. If even scientists are not fully in line on what is healthy, it is difficult for the general consumer to be completely confident that he or she is making the right choices.

As set out above, in **Chapter 4**, we found that self-efficacy had a significant negative effect on the percentage of healthy food choices made in some of our simplified regression models. This gives some room for the hypothesis that over-confident individuals who overestimate their own abilities to make healthy choices could potentially be negating the positive effect of self-efficacy on complex food choices. In **Chapter 5**, we further investigated this phenomenon in regression model using clusters of consumers. We found that there was some unaccounted variance in our model. This could explain that there is a limit to the effect of self-efficacy on healthy choices in this population of high-intenders. We concluded that future studies should aim to better understand the limitation of the effect of self-efficacy on the healthiness of food choices in this specific subset of consumers who have a high intention to eat healthily. In studies on the effect of self-efficacy on school performance, for instance, the limiting effect of overconfidence related to high self-efficacy has been postulated (Moores & Chang, 2009; Pajares & Graham, 1999), in this respect. Another avenue of interest in the relation between self-efficacy and healthy food choices has been mentioned by Huntsinger and Luecken (2004). They have noted that there might be a reverse causation between these variables, pointing to the fact that perceived healthy food choices may causally affect self-efficacy, instead of the other way around.

NUTRITION LITERACY AND NUTRITION INFORMATION USAGE IN FOOD CHOICES

Nutrition literacy is the ability to obtain, process, and understand nutrition information to make healthful diet-related decisions (Soederberg Miller, 2016). It is on the critical path of translating nutrition information into correct food choices. In two systematic reviews (Cowburn & Stockley, 2005; Sinclair, Cooper, & Mansfield, 2014), a plethora of evidence was provided to support the importance of the role of nutrition literacy in healthy food choices. Vaitkeviciute et al. (2015), in this regard, also highlighted that especially in adolescents, nutrition literacy plays an important role in their dietary intake. This particular study-population is characterized by frequent snacking, fast-food consumption and meal skipping, and thus are not likely to have a high intention to eat healthily. They are highly susceptible to have misconceptions about outcome expectancies (Croll, Neumark-Sztainer, & Story, 2001)

Across our research, we concurred that nutrition literacy is of importance in making healthy food choices. The research on understanding and processing of nutrition and health claims, as reviewed in **Chapter 2**, provided a detailed overview of why nutrition literacy is important in understanding nutrition and health claims. In this chapter, it was discussed that not only consumers should read available nutrition information, but also should be able to process it adequately, including understanding the scientific terms without going beyond reality (Mariotti et al., 2010). We set out that both from a legal

perspective, as well as a public health perspective, efforts should be made to increase nutrition literacy to avoid misinterpretations of nutrition and health claims. In **Chapter 3**, the complexity of proper nutrition literacy was exemplified. In this respect, the misconception that *high-fructose corn syrup* is very high in fructose, while in fact it is not that different from regular sugar, is fully understandable. Even with basic nutritional knowledge, such a misconception can occur due to the ambiguous name of this ingredient. For complex food choices, in which nutrition labels need to be evaluated, such information, however, is of utmost importance. As such, we argue that nutrition literacy among the general population needs to go beyond basic knowledge. It should be at a level at which consumers have the capacity to obtain, process, and understand nutrition information to make nutrition decisions that are in line with personal long-term health goals. One way of doing this, is to include lessons about the food and nutrients that we eat in educational programs from early age (Silk et al., 2008; Velardo, 2015)

In **Chapter 4**, we clearly identified nutrition literacy as an associative factor in complex healthy food choices through our sequential multiple regression analysis. Albeit not as strong as the frequency of nutrition information considered, nor as strong as a person's taste preferences, nutrition literacy was a significant determinant of the composition of the diet of highly educated health-minded individuals in our study. In this respect, we confirm the conclusion of **Chapter 3** and argue that nutrition literacy should be increased, perhaps through incorporating it in school curricula or through targeted public health campaigns (Velardo, 2015). Other research has suggested similarly to do this not only in health-minded individuals, but also in the general population. Increasing nutrition literacy helps to better read and understand (on-pack) nutrition information, which in turn could result in healthier food choices (Gibbs & Chapman-Novakofski, 2013; Rothman et al., 2006).

In **Chapter 5**, we could not confirm that there was a significant difference between consumer clusters on nutrition literacy scores. Although there could be some directional effect (p < 0.10) in which the *low information users* scored slightly lower on a nutrition literacy test than the other two groups, it could also be that there indeed is no direct effect of nutrition literacy on nutrition information usage. In this regard, the lack of direct effect might be related to the aforementioned over-confidence in our high-intention group of consumers. Many studies in different settings (i.e., general study populations and less complex food choices), however, have suggested that there is a direct effect of nutrition literacy on nutrition information usage (Carbone & Zoellner, 2012; Rothman et al., 2006; Velardo, 2015). Another explanation could be that in our study group of consumers who have a high intention to eat healthily, there is limited variance in nutrition literacy.

METHODOLOGICAL CONSIDERATIONS

The results of the studies in this thesis should be interpreted in the light of the strengths and limitations of the methodology used. In this section, the strengths and limitations of the study designs, study populations, and measurement of variables are considered. Moreover, a reflection is provided on the use of interdisciplinary research to address a single research problem.

Study designs

In **Chapter 2** and **Chapter 3** of this dissertation, we used narrative reviews to answer our research questions. Narrative reviews, in this respect, include the current knowledge on a specific topic, substantive findings from seminal research, as well as suggestions for theoretical and methodological contributions. Narrative reviews do not meet important criteria to help mitigate bias, as they lack explicit criteria for article selection. Our goal of these reviews was to assess the current state of research and helped to identify the key questions in the following chapters. The reviews were not intended to be a comprehensive, systematic review of evidence regarding better ways to let people engage in healthy nutrition behavior. They were designed, rather, to address practical cases on how European consumers in general perceive nutrition information, and how outcome expectancies are formed and distorted to make food choices.

In **Chapter 2**, specifically, we were able to propose a new framework to understand the effect of nutrition and health claims on outcome expectancies. Due to the narrative design of this research, the framework is not robust enough for any statistical test. It does, however, have practical relevance to structure discussions and findings related to nutrition and health claims as marketing tools. Similarly, our conclusions in **Chapter 3** are not embedded in a meta-analytic methodology. Our narrative review, provides a broad overview of these various health outcomes and mid-points, rather than a deep and robust view of a single health outcome.

In **Chapter 4** and **Chapter 5**, a more complex and quantitative approach was used. Specifically, we used process tracing software to monitor the use of nutrition information in dichotomous food choices. It should be noted that all measurements were conducted in a single session. We did carefully think about the order of questions (first psychosocial variables, followed by food choices, followed by taste preferences). It did, however, remain cross-sectional. Despite the specific order of our questions, we cannot rule out discussions related to causality, nor can we give information on long-term outcomes related to the food choices and the process that precedes making the choices (Berkman, 2017). Moreover, most individuals generally do not yet make food choices using a computer, besides the growing number of online grocery shoppers of course. Over the years, however, it has become clear that there are only limited differences between outcomes using an online convenience sample relative to

laboratory-based off-line research in social psychology (Casler et al., 2013; Riva et al., 2003). Moreover, if a similar study would be conducted in real life, participants would be required to wear eye-tracking devices while doing their shopping or choosing their products – which have their own limitations (Graham et al., 2012). Another limitation in our approach is the use of some branded products (e.g. Calvé peanutbutter). As discussed in **Chapter 2**, there is an effect of product brand on outcome expectancies, which we did not control for.

Study populations

In **Chapter 2** and **Chapter 3,** we explicitly focused on reviewing research relevant to the European general population. Although our conclusions in these chapters are quite universal in nature, it should be noted that there are large differences in food choice behavior between European cultures (Baker, Thompson, Engelken, & Huntley, 2004). Moreover, our recommendations should be treated carefully in populations outside Europe, for there is an immense cultural and geographical component to food choice behavior (Pieniak, Verbeke, Vanhonacker, Guerrero, & Hersleth, 2009). Across cultures, food is an integral part of one's identity and people from different cultural backgrounds eat different foods (Askegaard & Madsen, 1998). The ingredients, methods of preparation, preservation techniques, and types of food eaten at different meals vary greatly among cultures (Atkins & Bowler, 2016). Moreover, the area where you live influences food availability, and therefore food choices (Rozin, Fischler, Imada, Sarubin, & Wrzesniewski, 1999; Steptoe, Pollard, & Wardle, 1995).

For the research reported in **Chapter 4** and **Chapter 5**, participants were recruited through an existing online panel (academicresearchpanel.com). According to the panel administrator, this panel consists of more than 100 000 Dutch-speaking members who all indicated to be available to participate in scientific research, and all parts of the population are represented through careful panel management. Specific samples can be invited to partake in selected research. In our case, we recruited those who fit our inclusion criteria. We focused on consumers (>17 years old) who intend to eat healthily who were able to complete the survey on a computer with a mouse (no touch screen). As will be discussed in the recommendations for future research, our studies should be replicated in a broader population – including those who do not intend to eat healthily and in younger adolescents.

Unfortunately, participants in our study were not perfect representatives of the general Dutch population, based on their differing demographic characteristics. Our participants received higher education and had a different gender-distribution (more females) compared to the general Dutch population (Statline, 2016). This could affect the validity of our conclusions, as previous studies have shown that females are more health conscious, and thus might be more inclined to use nutrition information (Mai & Hoffmann, 2015). Moreover, one study in the United Kingdom has found that in women

with a higher educational attainment, there no effect of self-efficacy, perceived control or outcome expectancies on the quality of diet (Lawrence et al., 2011). This would mean that we have reduced variability in our dependent variable, and thus our analysis missed statistical power. In this respect, it should be noted that consumers who intend to eat healthily are in general more educated and more often female, according to a narrative review based upon a series of six systematic reviews (Brug, 2008).

In future work, our research should therefore be replicated in a sample of participants that are more in line with the general population. Moreover, as we will set out in the recommendations section of this chapter, the research should be conducted in groups of participants who have a low health and nutrition literacy and/or parts of the population in which there is a high prevalence of unhealthy behavior (high obesity, low socio-economic status, etc.). The study presented in **Chapter 4** and **Chapter 5** can be replicated rather easy in such a population. We expect this population will use less nutrition information, and that there will be a more clear effect of planning and nutrition literacy on healthy food choices as this population will be closer to the study-populations of earlier work studying these factors (Luszczynska et al., 2007; Silk et al., 2008; Velardo, 2015).

Measurement of variables

In the research presented in **Chapter 4** and **Chapter 5**, we built further on established questionnaires to measure psychosocial variables. In this respect, the intention to eat healthily was measured using four items from Schwarzer and Renner (2000), which was shown to have a high internal consistency. Similarly, questions related to action self-efficacy and coping self-efficacy were translated directly from Schwarzer and Renner (2000). Action and coping planning were quantified by adapting questions used by Luszczynska et al. (2007). For these constructs, we also added own questions per construct, which were specifically designed to measure the planning related to the behavior that is relevant to our study (i.e., dichotomous comparison of similar products). To our knowledge, no data is available on the validity of the used items.

We used the Nutrition Literacy Scale (NLS), as it was evaluated positively in multiple reviews (Carbone & Zoellner, 2012; Haun et al., 2014; Velardo, 2015), and because it was validated, also by dietitians, in multiple studies (Diamond, 2007; Nguyen et al., 2015). Since we administered the questionnaire to a Dutch population, we needed to translate the items in above questionnaires. In our translation, we needed to make some necessary adaptations (e.g., instead of referring to 5-servings of fruit/vegetables per day, we used the Dutch guidelines of 200-250 gram of vegetables per day). We ran a small (qualitative) pilot study in a convenience sample of 20 participants from our personal network to test for functionality and understanding. Based on the results of this pilot study, we could make needed improvements in the user experience and comprehensibility.

The questionnaire items used for the study in **Chapter 4** and **Chapter 5** remained self-reports of our participants' psychosocial status. Such self-reports are less accurate than objective observations as answers may be exaggerated, or respondents may be too embarrassed to reveal private details. Self-administered questionnaires, however, are commonly considered the most feasible and most inexpensive method for the assessment of psychosocial determinants in large-scale studies like ours (Conner & Norman, 2015). Although there are disadvantages (such as over- or underestimates by participants), the items we assessed (i.e., intention, self-efficacy, planning) are, in their essence, meant to be self-reported. As such, we do not expect this self-reporting to strongly affect our conclusions.

The self-reporting of food choices, even in large-scale studies, is subject to more debate, however (Cade, Burley, Warm, Thompson, & Margetts, 2004; Fairburn & Beglin, 1994). In general, food frequency questionnaires, which are designed to have participants self-report the frequency and in some cases portion size information about food and beverage consumption over a specified period of time, are considered poor indications of real food choices (Kristal, Peters, & Potter, 2005). In our research, therefore, we used the open source program MouselabWeb 1.00 beta (Willemsen & Johnson, 2011) to quantify food choice behavior. As discussed thoroughly in **Chapter 4** and **Chapter 5**, by using this innovative tool, we found an alternative approach to study food choices that focuses on the moment of choice, rather than looking back on previous choices.

Interdisciplinary research

New and effective policies, therapies, products and interventions are urgently needed to mitigate the serious public health consequences of dietary excess and deficit. Developing them will require a deeper understanding of the complex relationships between food, nutrition and health (V. S. Malik, Willett, & Hu, 2013). Throughout this thesis, it is argued that this insight can only be delivered through interdisciplinary and integrative research across the biochemical (basic and medical) and social (economic and behavioral) sciences that considers the multiple, interrelated factors contributing to human health and behavior. In this respect, in **Chapter 3** particularly, we take a food chemical composition-metabolic approach to understanding outcome expectancies of consuming foods with fructose-containing sugars. In **Chapter 2**, we address the legal and economic aspects of promoting outcomes of consuming specific foods. While in **Chapter 4** and **Chapter 5,** we take a much more psychological (behavioral) approach to the overall research problem.

There are also disadvantages to such an interdisciplinary approach. Particularly the differences in research cultures between the more hard biochemical sciences and soft social sciences have resulted in particular design (i.e., less rigorous narrative review vs. more rigorous randomized clinical trial) and reporting decisions (i.e., publishing towards

a broad audience vs. publishing in specialized journals). By using interdisciplinary research, it can be hard to reach the level of depth needed to spot true gaps in the current state-of-the-art in the complex field of food choices. Nevertheless, we felt that by exposing findings from one discipline to another, we fostered collaboration, hopefully resulting in strengthened research methods and arguments.

RECOMMENDATIONS

Our results and its comparison with other studies lead to a number of implications for practice and for future research. As a R&D manager in food industry myself, I am a practitioner of my own research. In the next sections, I detail how my peers in food industry could benefit from the research and how theory and future research can be improved.

For practice

Both with regard to developing new products, and in setting out applied research towards the effect of food components on health and profitability, **Chapter 2** provides an easy to remember framework for the usage of nutrition and health claims. Concretely, in any stage of development or research strategy, you should consider whether the consumers of the end-product *need the product*, *accept the ingredient*, *understand the benefit*, and *trust the brand*. Marketers in food industry could similarly apply this framework and, when appropriate, improve the consumer understanding of outcome expectancies when consuming a particular food (e.g., helping reduce blood cholesterol levels through wholegrain bread). **Chapter 3**, in this respect, provides an example of the misconceptions that can occur related to a specific ingredient. It shows that consumers will need to have a relatively high capacity to obtain, process, and understand nutrition information to align their outcome expectancies with reality. As we cannot expect all consumers to reach these high levels of nutrition literacy, there remains a large responsibility for food industry professionals to gradually limit the amount of fat and added sugars in products to reduce energy density. Moreover, they can help by using easy to understand back-of-pack information on the nutritional value of their products. It should be noted, however, that an overkill of nutrition labels – or using labels with ambiguous or false information – should definitely be avoided.

To ensure adequate nutrition for future generations, products need to be developed carefully, with the deepest of knowledge of the factors at play. The research presented in **Chapter 4** and **Chapter 5** help to shape our paradigms used to understand unhealthy food consumption. In this respect, the continuous refinement of existing theories is essential to support product developers in their effort to increase public health through industrially produced food. It might be worthwhile for product developers to include

"product healthiness" in their innovation procedures, for instance by including it as a continuation-gate in a stage-gate structured development project, as posited recently (Owen et al., 2013). As such, a manager or a selected committee of managers will need to "sign off" on a new product's healthiness before allocating more R&D resources.

Although the consumer will be responsible for the choices he or she makes, we concur strongly that there is a shared responsibility between retailers, food industry, governments and even schools to help the consumer to make an informed choice. By informing the public about the relation between nutrition and health, these shareholders can help tackle the current obesity epidemic (Hawkes et al., 2015; Roberto et al., 2015). Overall nutrition literacy should be improved to help consumers understand nutrition information.

We strongly feel that public health can be improved significantly by better understanding the lens that practitioners use to view the problem of unhealthy food consumption. As such, paradigms that include complex behavioral change theories need to be developed further to sharpen their view and to give concrete guidelines on how to address the problem. Current recommendations that cast aspersions on single nutrients and food components simply appear to be unsuccessful in improving overall diet, and a more wholesome approach is needed to give people the right tools to correctly incorporate food indulgences in their lives.

For theory and future research

The studies presented in this thesis aimed to contribute to our knowledge about how nutrition information affects food choices, with a focus on providing an interdisciplinary approach into the factors that attribute to the misfit between healthy diet intentions and behavior. For future research in this area, we have made some key recommendations throughout the thesis. Chiefly, we suggest that:

- Future research on studying food choices should focus on obtaining actual consumer behavior data, rather than self-reported preferences or production data
- Our process tracing experiment should be replicated in more broad and representative populations. It should be replicated in a population of which a considerable part does not have a high intention to eat healthily, and/or in a low-SES group. This could bring relevant additional information on the importance of the different factors studied in our model in the general population. It might be that in those who do not (yet) have an intention to eat healthily, outcome expectancies, self-efficacy and risk perception are more important in making healthy food choices than nutrition literacy and nutrition information usage. For public health, low-SES consumers are a relevant group as there is a high correlation between low-SES and consumption of unhealthy foods – and thus overweight and obesity (Gallus et al., 2015; Van Rossum et al., 2016). Thus, replication in individuals from lower

socioeconomic backgrounds is not only needed to gauge the generalizability of the findings following the replication in the broad population, but also because of the high impact it could have from a prevention-standpoint. In this respect, decreasing health differences between SES-groups is an important public health goal.

- To better understand how the studied attributes differ across populations, we propose to also conduct similar studies in adolescents. This particular study-population is susceptible to have misconceptions about outcome expectancies. Moreover, even findings ways to make small changes in their nutrition information usage can have positive long-term effects throughout the long life ahead of them. It is expected that in this group there is a lower level of planning, as well as intention to eat healthily as they are likely to be closer to the pre-intender side of the HAPA model (Croll et al., 2001; Vaitkeviciute et al., 2015).

- For further in-depth knowledge, our process tracing tool should be adapted to be used in an intervention-study, rather than a cross-sectional design as it was used in our study. By both obtaining baseline and follow-up data on how nutrition information is used within subjects, we can better study causality of the associations that we have found in our work.

- Although it might require participants to wear eye-tracking devices – which have their own limitations, our study should be replicated in a more real life context (i.e., supermarket and kitchen shelves).

Using data from the replication studies, new analyses can be conducted on the precise attributes that these individuals consider – related to their psychosocial characteristics. In this respect, we concur that there should be a specific focus on increasing nutrition literacy in lower-educated individuals, perhaps through targeted public health campaigns (Pendergast et al., 2011; Velardo, 2015).

Extending the conceptual model

In considering the tremendous amount of literature written already on this topic, the scope of this research by no means pretends to find all factors relevant to the relation between nutrition information and the quality of food choices. We acknowledge the wide range of disciplines involved in food consumption behavior, and consider alternative paradigms from the natural sciences – particularly in the first part of the dissertation. We specifically focus on nutrition information usage to explain the intention-behavior gap in healthy food choices.

Despite the limited scope of our conceptual model, our results induced a wide range of promising avenues for future study. By developing the lenses that we use to view the problem of unhealthy food consumption, we hope to stimulate further research that focuses on the consumers' skills to follow (inter)national dietary recommendations. In this respect, through this dissertation, learnings from health psychology are combined

with metabolic data to further improve our understanding of dietary recommendations. We signal that there is substantial ground for further study on how outcome expectancies are formed (**Chapter 2** and **Chapter 3**), and how nutrition literacy and nutrition information usage affet behavior (**Chapter 4** and **Chapter 5**), moderated by self-efficacy, and other psychosocial factors.

GENERAL CONCLUSION

For consumers who have an intention to eat healthily, using available nutrition information will enhance the healthiness of the food choices they make. Consumers not only need to pay attention to available nutrition information, our studies suggest that they should also comprehend this information for it to help them in deciding what to eat. In this dissertation, we look across scientific domains to further understand nutrition information and the role of outcome expectancies, intentions to eat healthily, planning, self-efficacy, and nutrition literacy in making food choices. We discuss that realistic outcome expectancies are integral in the relation between healthy intentions and nutrition information usage in the general population. Therefore, effective legislation on how nutrition information is presented is of great importance. Currently, the legislation provides some ambiguity resulting inadequately presented nutrition information. Moreover, we discuss that increasing ones nutrition literacy greatly benefits the comprehension of nutrition information. Nutrition literacy, in this respect, should be imparted using solid scientific evidence to avoid misconceptions about the health outcomes of consuming foods with specific nutrients (e.g., fructose-containing sugars).

In our study on consumers who have an intention to eat healthily, we find further evidence that both reading nutrition information, as well as high nutrition literacy, is of importance in making healthy food choices. This particular study population is motivated to become healthy, something which is often a hard-to-convey prerequisite for healthy behavior. Previous research has found that a consumer's confidence in his or her ability to successfully make healthy food choices (i.e., self-efficacy) is a prerequisite to have an intention to eat healthily. In our research, however, we find that it might not always benefit nutrition information usage. We believe to have given a deeper insight in explaining complex healthy food choice behavior by extending the HAPA model with nutrition literacy and nutrition information usage constructs. By using an interdisciplinary approach, and by using innovative methodology, further practical and theoretical advances can be made to help combat the public health problems related to unhealthy food consumptions. As some food for further thought, I end this chapter by paraphrasing another passage from Plato's the Protagoras:

There is far more risk in obtaining education than in obtaining food. When you buy food, you can store it before consumption, and consult an expert prior to consumption to avoid harm. When you obtain education, however, you cannot store it before consumption. You are compelled to take it in your soul immediately, unsure whether it will bring harm or benefit. Therefore, when choosing to obtain education, one should deliberate and take counsel with elders. (adapted from section 314a and 314b, Jowett, 1874).

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Summary

Healthy dietary intake patterns contribute to maintaining a good health and to the prevention of negative health consequences, such as hypertension. However, in spite of the negative effect of consuming unhealthy foods, which mostly are low-satiating, energy-dense, and have non-adequate quantities of micronutrients, consumers are still often engaging in food consumption behavior that negatively impacts their wellbeing. The usage of nutrition information, in this respect, can affect this food choice behavior. Next to reading this nutrition information, also the comprehension of this information is considered important in steering food choices, and thus dietary intake.

According to multiple scientific sources, available nutrition information is often used limitedly, or incorrectly, in making food choices. Even consumers who have an active long-term goal of consuming healthy foods, are found to not always utilize nutrition information to benefit their food choices. This group is characterized by having a strong motivation to become or to stay healthy. As can be expected, however, there is a strong heterogeneity between these people in how well their intentions are translated into behavior. In the second part of this thesis, we used a stage-model to describe how individuals move through a pattern of distinct phases when translating intention to behavior, derived from the *Health Action Process Approach* model. In doing so, we studied factors that influence how nutrition information affects food choices.

In the first part of this thesis, we addressed two specific cases where food consumption decisions were steered by information about components of food. In **Chapter 2**, we evaluated how European consumers perceive nutrition and health claims about specific food ingredients and what can be done to improve comprehension of such claims. We found that nutrition and health claims are mostly only perceived positive by specific target consumers (who need the product, accept the ingredient, understand the benefit, and trust the brand). These consumers indicate that the products with substantiated and approved claims help them in reaching overall health goals, and are therefore willing to buy products with these claims. Other consumers, however, may have adverse reactions towards nutrition and health claims on functional foods. We set out that both from a legal perspective, as well as a public health perspective, efforts should be made to increase nutrition literacy to avoid misinterpretations of nutrition and health claims.

In **Chapter 3**, a case study was presented in which nutrition information provided by various stakeholders is not in line with scientific findings. In particular, we evaluated why recommendations to reduce fructose-consumption are disputable and impractical given the current scientific findings on the relation between fructose and obesity. We argued that the proposition that the causal role of fructose intake in the etiology of the global obesity epidemic rests on controversial interpretations of research. When consumed in regular amounts, there appears to be no specific negative effect of fructose-containing sugars on obesity – besides the expected contribution to the energy balance. Accordingly, consumers should not avoid foods with fructose-containing sugars. This chapter provided another example of how food choices are not determined

solely by physiological needs (i.e., hunger or thirst), as they are dependent on many more factors, including consumer perception of how a food may influence his or her health – termed outcome expectancies.

In our overall conceptual model, we separated nutrition literacy as a distinct construct that influences how well intentions are converted into action, and added the role of demographic and psychosocial factors. In **Chapter 4** of this dissertation, this role was further discussed using data obtained from a survey in individuals who intend to eat healthily. Using process tracing software in a computerized task in which participants had to make dichotomous food choices, we measured the frequency and time of categories of nutritional information considered. In the research, we confirmed that, regardless of the increased aim to eat healthier, consumers often make choices that are not in line with their intention. The fundamental idea behind this phenomenon is the so-called intention-behavior gap. This phenomenon tells us that some people may develop an intention to perform healthy behavior, but they do not take the appropriate actions. We discussed that common psychosocial determinants of healthy behavior need to be augmented with a person's actual reading and understanding of nutrition information to better explain the variance in healthy food choice behavior.

In **Chapter 5**, we used the same date-set to form groups of consumers, who cluster on the level of energy, salt, sugar, and saturated fat levels considered. We did this to investigate differences between these groups and to see if consulting information on these "four evils" leads to healthier choices. We confirmed the importance of thoroughly reading available nutrition information to improve the healthiness of food choices in analyses of our online experiment. Remarkably, within our study population, consumers with high self-efficacy and a relative low intention to eat healthily (compared to others in our study) appeared to consult less information on energy, salt, sugar, and saturated fat. This could mean that some health-conscious consumers are overconfident in their ability to make healthy choices. These findings jointly build further on existing food choice models, and can help decision makers in public health and food industry to understand better the complex process of food choices, especially in those consumers who already have an intention to eat healthily.

In the general discussion of this dissertation (**Chapter 6**), a summary and integration of all the (main) findings of the preceding chapter is presented. Methodological issues are discussed, recommendations for future research and practice are given, and a general conclusion was drawn. We particularly focused on the role of outcome expectancies, nutrition literacy, and self-efficacy in food choices – which are often researched in other food choice studies. Self-efficacy, in this respect, might act as a double-edged sword. On the one hand, self-efficacy appears to operate on the formation of intentions to eat healthily, and thus in healthy food choices. On the other hand, based on data from our study with consumers who had a high intention to eat healthily, complex food choices might not benefit from an increased self-efficacy – as people can become overconfident and omit to use nutrition information. These

individuals might rely too much on the nutrition knowledge and beliefs that they already have, and make their (wrong) choices without using all available information. This needs further study.

For further theory building, we recommend to replicate our studies in **Chapter 4** and **Chapter 5** in a broad population, which does not have a high intention to eat healthily, a population of low-SES consumers, and a population of adolescents. Using data from these replication studies, new analyses can be conducted on the precise nutrition information attributes that these individuals consider – related to their psychosocial characteristics – to better understand their food choices. For practice, we argue that food industry should take responsibility in their role in the metabolic syndrome epidemic and use our findings to reformulate products, for instance by gradually limiting the amount of fat and added sugars in products to reduce energy density. We conclude that consumers now have access to a vast wealth of (mis)information, affecting their appetite and food choices. From both a practical and theoretical perspective, we need to further build our understanding how this information can be optimally used to promote healthy food choices.

Samenvatting

Gezond eten is belangrijk om gezond te zijn en te blijven. Het voorkomt negatieve gezondheidseffecten, zoals hypertensie. Ondanks dat het bekend is dat ongezonde voeding een negatief effect heeft op de gezondheid, maken consumenten nog vaak de verkeerde voedingskeuzes. Het gebruik van voedingsinformatie kan in dit opzicht het voedingskeuzegedrag positief beïnvloeden. Er is echter meer nodig dan alleen het lezen van deze informatie. De informatie moet ook begrepen worden, en omgezet naar adequate acties om effect te hebben op het voedingskeuzegedrag, en dus gezondheid.

Volgens meerdere wetenschappelijke bronnen wordt beschikbare voedings-informatie vaak beperkt of onjuist gebruikt. Zelfs consumenten die een actief lange-termijn doel hebben om gezonder te eten, blijken niet altijd de aanwezige voedingsinformatie juist te gebruiken om de gezonde keuzes te maken. Deze groep wordt gekenmerkt door een sterke motivatie om gezond te blijven of te worden. Vaak wordt die motivatie gezien als de belangrijkste stap om te komen tot gezondheids-gedrag. Binnen deze groep van gemotiveerde consumenten zitten verschillen in hoe de intenties om gezond te eten omgezet worden naar voedingskeuzegedrag. In het tweede deel van dit proefschrift proberen we deze verschillen te ontrafelen aan de hand van een model dat de stadia van gedragsverandering beschrijft en de factoren die in een bepaald stadium bepalend zijn voor het vertonen van het gedrag. Dit zogenaamde stagemodel is gebaseerd op het *Health Action Process Approach* model. Binnen dit model bestuderen we de factoren die invloed hebben op de relatie tussen voedingsinformatie en voedingskeuzes bij mensen die de intentie hebben om gezond te eten.

In het eerste deel van dit proefschrift behandelen we twee specifieke casussen waarbij voedingskeuzes worden beïnvloed door voedingsinformatie. In **Hoofdstuk 2** bestuderen we hoe de Europese consumenten van functionele voeding de voedings- en gezondheidsclaims over specifieke voedingsingrediënten beoordelen. We kijken met name naar wat kan worden gedaan om de begrijpbaarheid van dergelijke claims te verbeteren. We concluderen dat slechts een beperkte groep consumenten goed gebruikt maakt van deze claims. Slechts diegene die echt het product nodig hebben, het functionele ingrediënt accepteren, het gezondheidsvoordeel begrijpen en het merk vertrouwen hebben baat bij deze voeding- en gezondheidsclaims op functionele voeding. Andere consumenten kunnen neutrale, maar ook negatieve reacties hebben op voedings- en gezondheidsclaims. We wijzen erop dat zowel vanuit een juridisch perspectief als vanuit het oogpunt van de volksgezondheid moet worden gestreefd naar het vergroten van *nutrition literacy*, een construct dat iets zegt over hoeveel iemand van voeding af weet, om verkeerde interpretaties van voedings- en gezondheidsclaims te vermijden.

In **Hoofdstuk 3** behandelen we een casus waarin verschillende stakeholders voedingsinformatie uitgedragen die niet in lijn is met de huidige wetenschappelijke bevindingen. Specifiek hebben we het over fructose-houdende suikers, en de aanbeveling om het fructoseverbruik te verminderen. Wij stellen de vaak voorgestelde

causale rol van fructose-inname in de etiologie van de wereldwijde obesitasepidemie berust op controversiële interpretaties van wetenschappelijk onderzoek. We bespreken de huidige wetenschappelijke bewijzen en concluderen dat deze onvoldoende zijn om een causale rol van fructose in metabolische ziekten aan te tonen. We geven hiermee een tweede voorbeeld over hoe voedingskeuzes niet alleen bepaald worden door fysiologische behoeften (dat wil zeggen honger of dorst), maar ook door de consumentenbeleving van hoe voeding verwacht invloed uit te oefenen op gezondheid.

In ons algemene conceptuele model geven we *nutrition literacy* een centrale rol in de relatie in de omzetting van intenties naar gedrag, en relateren we dit construct aan demografische en psychosociale factoren. In **Hoofdstuk 4** van dit proefschrift wordt dit construct verder onderzocht met behulp van gegevens verkregen uit een studie bij personen die aangaven gezond te willen eten. Met behulp van de *proces tracing* software waarin deelnemers dichotome voedselkeuzes moesten maken, hebben we nauwkeurig de frequentie en de tijd van het gebruik van voedingsinformatie kunnen meten. Dezelfde deelnemers hebben een vragenlijst ingevuld over hun *nutrition literacy*. Het onderzoek bevestigt dat consumenten, ondanks hun doel om gezond te eten, regelmatig keuzes maken die niet in overeenstemming zijn met hun intentie. Het fundamentele idee achter dit fenomeen is het zogenaamde *intention-behavior-gap*. Dit fenomeen vertelt ons dat sommige mensen een voornemen kunnen ontwikkelen om gezond gedrag te verrichten, maar ze niet de juiste acties nemen. We bespreken dat reguliere psychosociale determinanten van gezond gedrag moeten worden aangevuld met het gebruik van voedingsinformatie en *nutrition literacy* om de variantie in gezond voedingskeuzegedrag beter te begrijpen.

In **Hoofdstuk 5** gebruiken we dezelfde onderzoeksdata om groepen consumenten te vormen die clusteren op het gebruik van voedingsinformatie over energie, zout, suiker en verzadigde vetten. We hebben dit gedaan om de verschillen tussen deze groepen te onderzoeken en om te zien of het raadplegen van informatie over deze 'vier kwaden' leidt tot gezondere keuzes. In lijn met onze hypothese bevestigen we dat beschikbare voedingsinformatie grondig gelezen en geïnterpreteerd moet worden om voedings-keuzes te verbeteren. Opmerkelijk is dat, binnen onze groep van personen die gezond willen eten, consumenten met een hoge zelf-effectiviteit en een relatief lage intentie om gezond te eten (binnen onze groep), minder informatie over energie, zout, suiker en verzadigd vet raadplegen. Dit kan betekenen dat sommige gezondheidsbewuste consumenten te veel zelfvertrouwen hebben in hun vermogen om gezonde keuzes te maken en daardoor meer uitgaan van de voedingsinformatie die ze al weten (en die al dan niet juist kan zijn).

In de algemene discussie van dit proefschrift (**Hoofdstuk 6**) integreren we alle bevindingen van de voorgaande hoofdstukken. We bediscussiëren methodologische uitdagingen en aanbevelingen voor toekomstig onderzoek. Ook geven we aan hoe ons onderzoek gebruikt kan worden in de praktijk. We benadrukken de rol van verwachtingen, *nutrition literacy* en zelfeffectiviteit in gezonde voedingskeuzes. Zelf-

effectiviteit speelt een interessante rol. Aan de ene kant heeft het een positief effect op het vormen van intenties. Aan de andere kant kan het leiden tot te veel zelfvertrouwen, althans in de groep die wij hebben bestudeert. Deze individuen kunnen te veel gaan vertrouwen op kennis en de overtuigingen over voeding die ze al hebben, en zouden hun keuzes (onterecht) kunnen maken zonder alle beschikbare informatie te gebruiken. In vervolgstudies moet dit verder onderzocht worden.

Voor verdere theorievorming raden wij aan om onze studies uit **Hoofdstuk 4** en **Hoofdstuk 5** te repliceren in een brede populatie, die juist niet van plan is om gezond te eten, een populatie van lage socio-economische consumenten en een populatie van adolescenten. Met behulp van gegevens uit deze replicatiestudies kunnen nieuwe analyses worden uitgevoerd op de precieze voedingsinformatie-attributen die deze personen overwegen – in relatie met hun psychosociale eigenschappen – om hun voedselkeuzes beter te begrijpen. De voedingsindustrie zou ook zijn verantwoordelijk moeten nemen voor hun rol in de stijgende obesitas-cijfers. Het onderzoek in dit proefschrift draagt bij aan het efficiënter herformuleren van producten, met als doel de consument een betere keuze te bieden. We concluderen dat consumenten nu toegang hebben tot een enorme hoeveelheid (verkeerde) informatie, die hun voedingskeuzes beïnvloeden. Zowel vanuit een praktisch als theoretisch perspectief is belangrijk dat we beter begrijpen hoe deze informatie het meest optimaal kan worden gebruikt om gezonde voedingskeuzes te bevorderen.

About the author

Vincent van Buul was born on February 11, 1988 in Vught, The Netherlands. After graduating secondary school in 2006 (Gymnasium Beekvliet in Sint-Michielsgestel), he started with his B.Sc. degree at the University College Maastricht (Maastricht University). In a Liberal Arts and Science study program, he obtained in-depth knowledge on the health and biochemical aspects of complex organic materials, focusing on food science. During his Bachelor's, he spent one semester at the University of Toronto (Canada), and one semester at Wageningen University (The Netherlands) studying biotechnology and food technology respectively. In 2010, he started a two-year Master's program in Health Food Innovation Management at Maastricht University's Campus Venlo. Here, he expanded his expertise in the social factors underlying purchasing behavior to better understand the value chain of food products. Next to his studies, Vincent co-founded a study association (International Study Association Umami) and a novel student information office and bar (The Hub). He completed his Master's with an internship at The Coca-Cola Company in Brussels (Belgium). Following his graduation in 2012, he worked for Maastricht University as a junior lecturer and researcher – conducting research sponsored by the Dutch Bakery Association and other industry partners – under Prof. Fred Brouns' supervision. Although remaining to be interested in fundamental research, he chose to work for food industry in 2014. For four days per week, Vincent worked as a New Product Development Manager at Gruma Netherlands B.V., a subsidiary of Gruma, S.A.B. de C.V., a Mexican multinational corn flour and tortillas manufacturing company. One day per week, Vincent devoted to combining the research he conducted as a junior researcher with new research under the supervision of Prof. Lilian Lechner and Prof. Catherine Bolman at the Open University. During his time at Maastricht University and Open University, Vincent presented his research to peers in international gatherings including the 2014 AMA-Sheth Foundation Doctoral Consortium (Chicago, United States) and the 2017 Rank Prize Symposium (Grasmere, United Kingdom). From January 2018 onward, Vincent works full-time for Gruma, continuing to be a member of the Dutch site's Management Team, leading the new product, packaging and process development group. Next to his responsibilities in the Netherlands, he became responsible for coordinating the European R&D efforts of Gruma's tortilla-manufacturing sites in the United Kingdom (2), Spain (2), The Netherlands (1), and Russia (1).

Publication list

PUBLICATIONS PRESENTED IN THIS DISSERTATION

van Buul, V. J., & Brouns, F. J. P. H. (2015). Nutrition and health claims as marketing tools. *Critical Reviews in Food Science and Nutrition*. 55(11), 1552-1560.

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MANUSCRIPTS UNDER REVIEW

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OTHER PEER-REVIEWED PUBLICATIONS

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