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Behavioural Insights and (Un)Healthy Dietary Choices:

A Review of Current Evidence[1]

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Abstract This paper reviews the current evidence about behavioural insights in the field of (un)healthy food choice that can support the development of behavioural public-policy tools. It extends previous work on behaviourally based policies in health and food choice, both academic and professional. The core of the paper is a summary of reviews of behavioural insights-based interventions and the scientific evidence regarding their efficacy in nudging people towards healthier food choices. Overall, we cover 39 systematic literature reviews and meta-analyses published between 2010 and 2017. Additionally, we outline potential drivers and theories that could help to explain the mechanism behind these interventions. The paper concludes with a discussion of the results and suggestions for policy-makers aiming to make use of behavioural insights in health policy.

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In spite of an unparalleled supply of healthy food in the industrialized world today, unhealthy diets – feeding into high levels of obesity and noncommunicable diseases, which in turn lead to social, psychological, and economic disadvantages – are a core issue of modern public health policy. Decision-makers on all levels, from the global reach of the World Health Organization to the local community school principal catering lunches to children, face the same challenge: How can we foster healthier food choices in a way that people ideally stick to them over a longer time period? Behind this practical question lies an academic one: What is the scientific evidence about what determines (un)healthy food choices, and how can this knowledge be used to design better policies?

In the field of dietary choices and healthy lifestyles, classic policy tools have a long tradition – and a rather mixed record of accomplishment (e.g., Brambila-Macias et al. 2011 for a review). Banning unhealthy foods is unlikely to be a suitable instrument, as the evidence for the causal determinants of rising obesity rates remain highly debated, making it difficult to single out particular nutrients, products, or practices (e.g. see Casazza et al. 2013; Herman et al. 2016; Hill and Peters 1998; Lucan and DiNicolantonio 2015; Lusk and Ellison 2013; Swinburn et al. 2011; Young and Nestle 2002). Nevertheless, policy-makers increasingly use taxation, primarily on sugar-sweetened beverages and other unhealthy food (i.e., high in fat, sugar, or salt) to reduce their demand. This is a potentially effective approach, as studies find the demand to be price-elastic (Afshin et al. 2017; An 2013; Andreyeva et al. 2010; Eyles et al. 2012; Maniadakis et al. 2013; Powell and Chaloupka 2009; Powell et al. 2013). Evidence on obesity is more limited (Maniadakis et al. 2013), and the disproportional burden on the less affluent remains a general concern. An alternative might be specifically targeted subsidies for healthy foods (see Bartlett et al. 2014), as population-wide price reductions might be overly costly and can be expected to widen health inequality (Muller et al. 2017).

Further approaches concern the limitation of marketing, which seems to promote consumption of nutritionally poor foods, at least among children (Boyland and Whalen 2015)

– a fact potentially related to the conclusion of recent studies that self-regulation by the food industry is, on average, unsuccessful and inefficient (Kunkel et al. 2015; Ronit and Jensen 2014). Social marketing initiatives through the public to educate, enable, and empower consumers by informing them about healthy food choices have been a widely used policy tool over several decades. Even though most adults are familiar with such information, only a few seem to follow the provided healthy-eating guidelines in practice (Guthrie et al. 2015). Given the development of obesity despite such initiatives (NCD Risk Factor Collaboration 2017), it is reasonable to argue that solely – or even largely – relying on educating and informing consumers seems to be insufficient to reduce obesity levels.

Therefore, a more detailed understanding of why people make unhealthy food choices and how to promote healthier decisions is critical to prevent obesity. Consumer research has long studied human decision-making processes and resistance to change in areas such as environmentally friendly and healthy choices (e.g., Reisch and Thøgersen 2016). There is a rich literature based on cognitive psychology, social psychology, judgement and decision-making research, neurobiology and behavioural economics, among others, that has developed methods, theories, and empirical evidence regarding (un)healthy food choices. It is widely acknowledged that food decisions are embedded in highly complex food systems (Story et al. 2008) and influenced by an array of individual (psychological, physical, neurological), social, and environmental factors. The latter have been described as making up an "obesogenic environment" (Berthoud 2012) and depicted as an important (since potentially malleable) entry for policies (Swinburn et al. 2011).

Successful policies promoting healthier food choices have to consider the multiplicity of these factors along with peculiarities of the specific target group regarding age, social status, health status (BMI), as well as goals, values, and other psychographics. In an ideal world, policies are based on robust evidence of how these factors influence (un)healthy food choice, how they are interlinked, and which policy tools are the most effective, efficient, socially

approved of, as well as politically enforceable to nudge consumers into healthier directions. While policies to foster healthier food choices are manifold and have been discussed for decades, a new strand of consumer research focuses on behavioural insights-based policy tools or "nudges" for healthier food decisions (e.g., Brambila-Macias et al. 2011; Reisch et al. 2017; van Kleef and van Trijp 2018).[3]

Behavioural insights can influence policy design via three potential pathways: Firstly, they can improve the efficacy of the classical tools, e.g., when making consumer information more salient, relevant, and accessible. Secondly, they offer new policy tools that are less intrusive and more flexible than bans and taxes, e.g., when deciding to serve "healthy defaults" in public canteens. Thirdly, using behavioural insights in policy design calls for an empirically based policy-making process based on a "test-learn-adapt" approach, using experiments, running pilot tests, and improving policies with an empirical and iterative process (Halpern 2015; Shafir 2013; Sousa Lourenço et al. 2016).

The goal of the present paper is to review the current evidence about behavioural insights in the field of (un)healthy food choice that supports the development of behavioural public-policy tools. The paper extends previous work on behaviourally based policies in health and food choice, both academic (e.g. Brambila-Macias et al. 2011; Capacci et al. 2012; Cecchini et al. 2010; Cohen et al. 2016; Hawkes et al. 2015; Just and Payne 2009; Loewenstein 2012; Roberto 2015; Schwartz et al. 2017) and professional (BIT 2015; GreeNudge 2017) and thereby contributes to the rapidly growing literature on people's food choice and behavioural insights-based stimuli used to nudge these choices in healthier directions. The paper does so by providing an overview of current empirical results in this field, published in 39 review papers in scientific journals between 2010 and 2017. Since this knowledge is dispersed over different fields of research and published in diverse disciplinary

[3] For instance, the current EU FP7 project "Nudge-it" (https://www.nudge-it.eu/) and the Dutch Project "NUDGIS" (https://www.nwo.nl/en/research-and-results/research-projects/i/11/11011.html)

journals, the paper offers an easy-access overview and reflection of this voluminous research. To the best of our knowledge, this has not been provided to date. Moreover, we contribute to the debate on behavioural insights-based public health in particular and consumer policy in general by reviewing the available evidence regarding the effectiveness of some key "health nudges." With this, we respond to recent calls for research in this area (e.g., Reisch et al. 2017; Wilson et al. 2016).

We start with a brief discussion and delimitation of the behavioural insights-based interventions reviewed in this paper and how they can be systematized. Thereafter, we describe how the review articles were obtained. The core of the paper then presents an overview of these different behavioural approaches and the scientific evidence regarding their efficacy. Additionally, we outline potential drivers and theories that could help to explain the mechanism behind these interventions. The paper concludes with a discussion of the evidence and implications for consumer policy.

Behavioural Policy Instruments to Foster Healthy Food Choices

In Behavioural Public Policy (BPP) (e.g., Shafir 2013), a nudge is defined "as any aspect of the choice architecture that alters people's behaviour in a predictable way without forbidding any options or significantly changing their economic incentives. To count as a mere nudge, the intervention must be easy and cheap to avoid" (Thaler and Sunstein 2008, p.6) (also see Sunstein 2018; Sunstein and Thaler 2003). The core theoretical base of BPP can be found in cognitive psychology, particularly in the so-called dual process theory (Kahneman 2003, 2013), which emphasises a more nuanced way how people make decisions beyond the neoclassical axioms.

Systematizing Behavioural Instruments: A Pragmatic Approach

While Richard Thaler and Cass Sunstein have provided and elaborated upon explicit definitions, the multi-disciplinary field of "nudge science" is still trying to incorporate the umbrella concept into its field-specific terminologies, theories, perspectives, and interests. Despite several attempts (Blumenthal-Barby and Burroughs 2012; Hollands et al. 2013; Hollands et al. 2017; Ly et al. 2013; Michie et al. 2013; Münscher et al. 2015), scholars struggle to precisely distinguish and categorize the different interventions in a mostly empirical field.[4]

In a pragmatic approach, leaving conceptual debates aside and taking on a regulator's view, Sunstein (2014) listed the ten most important nudges for policy-making as follows: (1) default rules; (2) simplification; (3) use of social norms; (4) increases in ease and convenience; (5) disclosure; (6) warnings, graphic or otherwise; (7) pre-commitment strategies; (8) reminders; (9) eliciting implementation intentions; and (10) informing people of the nature and consequences of their own past choices.

The current field of research in food choice has focused more on some of these categories than others, and the lines are blurry. Particularly regarding food labels, the literature often makes little distinction between nudging and the use of behavioural insights to improve the way people understand and use (the classical policy tool of) nutritional information (see Sousa Lourenço et al. 2016). Labels convey factual information about nutrition and also work as a reminder to eat healthy. The empirical exploration of effective

[4] Whether this is an opportunity to develop dynamic and field-specific nudge concepts or whether this lack of a general taxonomy is deplorable – and whether such an overarching typology is desirable at all – are debatable. The specific potential and limits of nudges can, however, only be revealed case-specifically; in our view, increasing the level of abstraction might be an interesting academic exercise but is not helpful in the real world.

behavioural tools is closely intertwined with the testing of successful nudging interventions, making the conceptual distinction difficult.

In the present paper, as displayed in Table 1, we rely on a slightly adapted version of a taxonomy previously developed for the field of health care (Perry et al. 2015). This taxonomy offers a practical and simple structure to present the existing literature in the area of food choice and health nudges. We suggest that a not too detailed but rather general taxonomy is the best approach for our goal here since the original studies reviewed have used a variety of taxonomies. Trying to fit these multiple typologies post hoc into one scheme seems neither appropriate nor useful.

- Insert Table 1 about here -

Methodology

We conducted a search via Scopus (see Table A1 for the search terms), selecting systematic reviews and meta-analyses published between 2010 and 2017 that compiled results of behavioural interventions on food choices. More concretely, we restricted the search to peer-reviewed articles assessing interventions that influenced food decisions through the way the choice situation was designed. We therefore excluded behavioural research on fostering individuals' ability to make better food choices through *other* approaches (e.g., through education, behavioural therapy, or mindfulness training). While such learning techniques are certainly of value, we were only interested in the five behavioural approaches or "nudges" presented in Table 1. Individual characteristics including nutritional education are however discussed as potential moderating factors for the main interventions of interest.

The initial search revealed 1,477 articles, from which 34 reviews remained upon closer inspection (see Figure A1). We added five more reviews (which had not been found through the database search) identified through reference searches and alternative sources. Overall,

our selection yielded 39 papers (as presented in Table 2). For the types of interventions where no specific overview paper was found, we did not conduct a systematic review of individual studies. This would have been beyond the scope of this paper but implies that we cannot claim to present an unbiased overview for the respective intervention and their effectiveness. To outline the potential underlying mechanisms, we rely on illustrative studies that should also be considered exemplary rather than comprehensive.

General Overview

The emerging field of active and deliberate design of settings and contexts for healthier choices has been covered in several recent reviews that often vary in their definitions of nudging and choice architecture (e.g., Arno and Thomas 2016; Broers et al. 2017; Bucher et al. 2016; Wilson et al. 2016). Some of these reviews focus on specific settings such as schools (Nørnberg et al. 2015), universities (Roy et al. 2015), and self-service settings (Skov et al. 2013); others cover workplace interventions (Allan et al. 2017) or children in their home environment (Lycett et al. 2017). Other reviews focus on specific ways food is presented, such as type of tableware (e.g., Holden et al. 2016), or have not focused on choice but rather included relevant literature while reviewing a wider set of interventions to foster healthier choices (e.g., Hillier-Brown et al. 2017; Kahn-Marshall and Gallant 2012).

To the best of our knowledge, only two meta-analyses were published until 2017 that specifically focus on *nudging interventions and food choices*.[5] The meta-analysis by Arno and Thomas (2016) is based on 42 nudging interventions, including the use of food labels, and it finds an average 15.3% increase in healthier consumption decisions. The analysis included studies with different outcome measures ranging from healthier choices and frequency of

[5] An unpublished meta-analysis of 277 effect sizes by Cadario and Chandon (2017) finds calorie reductions between -45 and -186 kcal. The authors argue that using the "right" nudge for the specific context can boost effects substantially.

choice to consumption. “Healthier” was defined as comparably lower in calories, salt, sugar, cholesterol, and fat, or higher in nutrient density, such as vegetables, fruits, and whole grain. The second meta-analysis (Broers et al. 2017) focused on nudges fostering the choice of fruit and vegetables and found a modestly significant and positive effect of nudging interventions altering placement and properties of food choice, sales, and servings (Cohen’s d = 0.3).

The conclusion that nudges hold promise in fostering healthier food choices is supported by virtually all reviews (e.g. Bucher et al. 2016; Skov et al. 2013). For instance, of the 40 studies covering interventions that nudge children to healthier choices, 33 (83%) found a positive effect on dietary behaviour of children (Lycett et al. 2017). However, a final judgement is often considered complicated and unclear, as studies differ substantially in type and quality of design, which makes it difficult to reach a conclusion in terms of overall effectiveness (Nørnberg et al. 2015; Skov et al. 2013; Wilson et al. 2016).

Improving the Provision of Nutritional Information

The need for nutritional information to support consumer food choices is generally agreed on by all stakeholders (Storcksdieck Genannt Bonsmann and Wills 2012) and is reflected worldwide in regulatory work and market practice. Nearly all Western countries have regulation in place that requires some display of nutritional information of the food items, with EU-wide mandatory labelling since 2016 (European Commission 2014).

Despite the efforts, the provision of nutritional information has a mixed record of accomplishment regarding influence on actual food choice. The rather limited effects of factual information highlight the importance of *whether* and *what* information should be provided (Grunert and Wills 2007; Storcksdieck Genannt Bonsmann and Wills 2012), as well as *how* this information is portrayed (Sunstein 2013). A key learning from behavioural insights is that information has to be provided in a manner that takes actual human behaviour into account, and this requires detailed analysis of the way people process nutritional

information in real life and a holistic understanding of what determines actual food choice (Leng et al. 2016).

One major theme of behaviourally informed policy-making is *simplification*. Most people are not willing to invest substantial effort in understanding overly complicated information. To be effective a policy or nudge must avoid ambiguity and be simple and specific about what exactly should be done (Sunstein 2013). This principle extends to procedural knowledge that helps translate the goal to improve diets into healthier food choices (Dickson-Spillmann and Siegrist 2011). According to Miller and Cassady (2015), this general distinction between procedural and factual knowledge in food choices has received comparably little attention in the past, but it might help us to understand how nutritional information can be more effective. Interventions with the aim to improve consumer understanding of nutritional fact labels have generally shown some positive effects, including among high-risk groups such as households with low socio-economic status (Campos et al. 2011). Most studies suggest a link between nutritional knowledge and the use of food labels, as well as comprehension of the latter. As nutritional knowledge is positively linked to healthier food choices (Spronk et al. 2014), it is difficult to isolate a clear causal link among the three aspects. However, research in cognitive psychology suggests that prior nutritional knowledge not only correlates with label use but also helps to direct consumer attention, promotes comprehension, and increases the effect on food choice (Miller and Cassady 2015).

Even though many consumers are able to understand the provided nutritional information, the impact of these labels on choice during the actual process of shopping seems limited (Wills et al. 2009). Campos and colleagues (2011) reviewed the use and understanding of the nutritional facts label on packaged food. Of the 120 studies in their review, 65 reported frequency of label use. Even though different definitions of label "use" complicate the comparability among the studies, it was found that generally more than 50% of consumers use nutritional information on packaged foods in their decision-making. Those

users tend to be young, female, better educated, and likely to attribute greater importance to healthy diets. Usage was negatively associated with a lack of time for shopping and limited financial resources.

However, many consumers have difficulties with quantitative information, especially with percentages of daily amounts, serving sizes, or other reference information. Additional confusion arises when consumers are required to compare different products on the basis of per serving or a standardized reference, as this requires calculation (Campos et al. 2011). Such difficulties are hardly surprising given that people's lack of time, attention, and motivation often pose a major barrier to the use of on-package nutritional information. Eye-tracking research for the FLABEL project,[6] for instance, suggests that consumers spend less than one second looking at a nutritional label when choosing a product (also see Storcksdieck Genannt Bonsmann and Wills 2012). Finally, functional illiteracy is an often underestimated challenge even in many industrialized countries and might impair people's ability to read, understand, compare, and evaluate the information provided (Cha et al. 2014).

Nutritional Information in Supermarkets and on Pre-packaged Foods

In line with the WHO's call to "increase consumer-friendly labelling by establishing easy-to-understand or interpretative front-of-package (FOP) labels" (WHO, Regional Office for Europe 2014) as part of its European Food and Nutrition Action Plan 2015–2020, many consumer advocates promote efforts to simplify the presentation of nutritional information (Campos et al. 2011; Grunert and Wills 2007; Sunstein 2013). One prominent simplification is the introduction of nutritional labels that include colour coding (e.g., "traffic-light schemes") or other ways to reduce complexity. A variety of simplified and/or FOP labels have been put forward to increase salience and ease of use, including most notably the

[6] Food Labelling to Advance Better Education for Life, http://flabel.org/.

provision of reference by the Guideline Daily Amounts (GDA) and the use of colours by the (Multiple) Traffic Lights ((M)TL). An additional label uses a "keyhole" or "Green tick"[7] to signal comparatively healthier products within a certain food group (see Figure 1).

- *Insert Figure 1 about here -*

The effects of these labels on food choice and consumer behaviour have been widely studied and summarized in recent reviews (Cecchini and Warin 2016; Hawley et al. 2013). A meta-analysis on the impact of food labels on choice and caloric intake concludes that labels have a positive effect on healthy food choice, showing that people choose the healthier option from different alternatives 18% more often compared to the control groups without labels. TL labels were more effective compared to the GDA and various other forms of labels. With regard to calorie choice/intake, no significant effect was found, which could suggest that people might eat more of those foods that are labelled as healthy. The authors emphasize that most of these studies were conducted in controlled laboratory environments and provide little external validity for real-life scenarios (Cecchini and Warin 2016). However, some long-term studies that exploit the implementation of compulsory nutritional package information offer some evidence that such information helps to improve dietary choices on the population level (Campos et al. 2011; Variyam and Cawley 2006).

The effectiveness of the (M)TL is supported by another review focusing on distinct aspects of FOP labels. Hawley et al. (2013) conclude that the (M)TL has the most empirical support, and that it should include calories per serving and daily caloric requirements and identify specific nutrient levels in clear text. Also, the label should be sufficiently large and displayed on the top-right corner of the package. Hawley and colleagues (2013) argue that not

[7] This label is recently facing criticism in the Netherlands after research showed a lack of understanding among consumers despite the label being implemented for the past ten years (Consumentenbond 2016).

all but rather only those nutrients with the largest impact on population health should be highlighted. Most research suggests that consumers tend to primarily look at ingredients they want to avoid (disqualifying), with a main focus on fat, energy content, cholesterol, and carbohydrates (Azman and Sahak 2014; Campos et al. 2011). However, findings based on a large online survey of residents in six European countries suggest that people on average find nutritional information about desired nutrients (qualifying), such as vitamins and fiber, more important than disqualifying information (Hoefkens et al. 2011). The importance of the latter appears to be more heterogeneous among different consumer segments and seems to be of particular relevance for health-conscious people.

In addition to the mostly empirical debate about effectiveness of labels, Muller and Prevost (2016) assess the most prominent labels from the perspective of cognitive psychology. With regard to the processing speed and ease, meaningful colours are better than numbers, fewer dimensions are better than more (preferably only one instead of several different nutrients such as fat, salt, and sugar), and, with some caution, comparison within a product category is easier than judging on absolute content or against daily guidelines. The idea that effective nutritional information should be directive and not only descriptive was already highlighted by previous research (van Herpen and van Trijp 2011).

Studies using fMRI data to compare the activation of brain areas when using colour (TL) or numbers (GDA) in food labels reveal further insights about the way labels are processed. While Enax et al. (2015) showed that different colours activate different brain areas related to self-control (red) or reward expectation (green), Prevost and colleagues (2017) concluded that even though colour coding resulted in faster responses, both labels were mostly evaluated by brain regions associated with processing arithmetic and complex information. This finding runs contrary to the researchers' hypothesis that judgements based on colour would significantly rely on emotions (Prevost et al. 2017). This conclusion that the

use of contextual information in colour is important to make healthier choices easier was shared by the review by Hersey et al. (2013).

Against the backdrop of recent research (Muller and Prevost 2016), the 5-Color Nutritional Label (5-CNL) was recently proposed in France. Similar to the EU Energy Label, the 5-CNL provides a univariate classification based on a multiple-components score ranging from a green "A" to a red "E" (Julia et al. 2015). In a web-based randomized controlled trial, Ducrot and colleagues (2016) compared the effect of different labels in an online supermarket scenario. Compared to an unlabelled control, all label treatments – except for the GDA – led to a lower overall calorie content in the shopping basket. Overall, the 5-CNL outperformed the Green tick and the MTL. However, results from a real-life supermarket setting showed less effect on food quality purchased. Among three food categories the 5-CNL (only when combined with additional information) led to healthier choices of sweet biscuits but had no effect on appetizers or breakfast cereals (Julia et al. 2016; Julia and Hercberg 2017). Despite the limited effectiveness of the 5-CNL in real-life settings, France is currently rolling out the label in a widely accepted voluntary scheme as part of the WHO European Food and Nutrition Action Plan 2015–2020.

Nutritional Information in Restaurants and on Menus

Another area where nutritional information can provide guidance and foster healthier food choices is restaurants. Provision of calorie information and suggested daily intake is required by the FDA for all U.S. chain-restaurants with more than 20 locations (Long et al. 2015). Most recently, studies trying to measure the impact of this law find positive effects on Body Mass Index (BMI). For instance, a yet unpublished study exploits U.S. county variation in the introduction of food label laws; it finds reduced BMI levels for overweight women (but not for women with normal weight or obesity) and for all weight groups of men, with stronger

effects among overweight and obese men (Deb and Vargas 2016). Using only data from the implementation in New York (Restrepo 2017), results show that menu labels reduced BMI by 1.5% and lowered the risk of obesity by 12%, with a more pronounced effect among lower-income individuals.

Overall, the effect of calorie information on food choice is a quickly growing field of research and was the subject of several reviews since 2010 (Bleich et al. 2017; Fernandes et al. 2016; Kiszko et al. 2014; Littlewood et al. 2016; Long et al. 2015; Nikolaou et al. 2015; Sacco et al. 2017; Sinclair et al. 2014; Swartz et al. 2011). Even though the results are mixed, all reviews highlight the importance of the way information is provided and call for further research to find the most efficient design for specific settings.

Littlewood et al. (2016) conclude that calorie information on menus on average effectively reduces the energy content of foods ordered and consumed. Note that results varied between settings (real-world vs. laboratory/hypothetical) and outcome variable (order vs. consumption). Only three studies reported no significant effect of labelling. On average, the meta-analysis found a mean reduction in consumption of 100 kcal attributed to the menu labels. In studies conducted in real-world settings, labels have been estimated to reduce choice by 78 kcal. This overall positive review of recent studies contradicts the findings of other reviews, which often report null or inconclusive results.

For instance, Bleich et al. (2017) argue that there is a need for well-designed studies that would allow evaluation of the overall effectiveness of calorie information. Long et al.'s (2015) systematic review of the impact of menu labels found a small but significant reduction of calories. While the full data showed a reduction by 18 kcal, the sub-analysis of the real restaurant data yielded only an insignificant reduction by 8 kcal. This is echoed by a meta-analysis by Cantu-Jungles et al. (2017) for the U.S. concluding that restaurant labels neither reduce quantity nor improve quality of diets. Like another review focusing on children's and adolescents' use of menu labelling (Sacco et al. 2017): the positive experimental (lab) results

could not be confirmed by the reviewed field studies. Fernandes et al. (2016) exclusively reviewed real-life settings and found evidence to be mixed, with only 65% of studies reporting a partial or overall positive effect of menu labelling. Effects were stronger in cafeteria settings and for the use of simplified logos. That effects can differ between real-life setting was also suggested by van Epps et al. (2016), who found menu labels to be more effective in cafeterias than in classical fast-food restaurants.

Earlier reviews had concluded that the mere provision of calorie information on menus has little to no effect on total calories consumed (Kiszko et al. 2014; Sinclair et al. 2014; Swartz et al. 2011). For all 17 studies combined, Sinclair et al.'s (2014) meta-analysis suggests a reduction of about 40 kcal selected as well as consumed. However, a sub-group analysis revealed that the results were mainly driven by studies including further contextual information that eases interpretation such as traffic-light symbols, exercise equivalent labels, recommended daily caloric intake, and low-high fat labels. Calorie information alone had no significant effect. The conclusion that the sole provision of information is unlikely to have strong effects was echoed by a review of interventions of ready-to-eat foods sold by food outlets (Hillier-Brown et al. 2017).

No or only a modest effect on calorie ordering and consumption was a conclusion echoed by two other reviews: Swartz et al. (2011) reviewed experimental and quasi-experimenal designs conducted in laboratories, college cafeterias, and fast-food restaurants. Kiszko et al. (2014) used a wider set of studies that also includes hypothetical choices; they concluded that the most reliable studies show little effect of calorie labels on the energy content people chose.

The importance of design and context of the label was highlighted by virtually all reviews. Even though contextual information was not directly associated with improved label use in Littlewood et al. (2016), the authors noted that insignificant effects can partly be ascribed to the fact that consumers did not notice the provided information. Hence, salience is

likely to increase effectiveness of menu labelling (also see Kiszko et al. 2014; Nikolaou et al. 2015; Sinclair et al. 2014).

Concerning effect heterogeneity based on consumer characteristics, results from the reviews are mixed. Littlewood et al. (2016) found little difference between socio-demographic groups, which led the authors to conclude that menu labels are an equitable initiative. This finding differs from Sinclair et al.'s (2014) conclusion that women tend to be more responsive to nutritional information, emphasizing the need to consider effect heterogeneity with regard to the target population. Supporting – yet inconsistent – evidence regarding the relevance of gender, weight, and socio-economic status was identified in adolescents and children (Sacco et al. 2017).

Depending on individuals' prior beliefs about the caloric content of meals, provision of calorie information might even have unintended adverse effects on food choice. While such beliefs can vary among restaurant types or brands, they are an important factor mediating the effect of displaying nutritional information. A study comparing customers of Australian quick-casual restaurants with and without menu labels showed that people generally overestimate the caloric content of the offered foods. Providing calorie information on menus encouraged even higher consumption and increased the number of calories purchased (Seenivasan and Thomas 2016) – which is quite the opposite of the intended effect.

Making Health Salient and Healthy Food Choices the Norm

Even though the environment plays an important role in explaining and predicting individual behaviour, external stimuli should not be seen as simply pushing a mental button that triggers a specific behavioural response. The idea of goal activation (e.g., Aarts and Elliot 2012) implies that such stimuli are evaluated based on their relevance for various existing goals. Hence, individuals with different goals (lose weight vs. indulging in food) might respond

differently to a similar stimulus. Also, a single individual often has different goals that are incompatible. Behaviour in the case of such goal conflict might be the result of careful goal balancing, but it also depends on situational aspects. For goals to guide behaviour, they have to be salient and accessible in memory at the moment of decision-making and require goal activation. The latter can be achieved through cues from the environment and learned associations (Papies 2016a).

Pursuing a long-term goal, such as sustaining a healthy diet, requires self-regulation that helps to maintain goal-congruent behaviour and avoidance of temptations that trigger short-term hedonic goals, such as a delicious-looking dessert (Aarts and Elliot 2012; Förster et al. 2007). However, impulsive food decisions appear to systematically gravitate towards choices high in fat and sugar – which has been explained as learned associations between consumption of calorie-dense foods and their reward outcome (Higgs 2016). That these foods are particularly rewarding is presumably linked to evolutionary reasons, as focusing on high energy in a food-scarce environment might be advantageous for survival (Volkow et al. 2011).

People with the intention to eat healthy have to forgo such immediate rewards and exercise self-control. For self-control to be successful, the cognitive structures related to the health goal require activation in the moment of decision-making. Particularly under conditions unfavourable to proper cognitive reflection – such as hunger or high cognitive and emotional load – people are more likely to rely on automated processes (Hofmann et al. 2008).

However, when decision-making about food takes place, health aspects are not the only cognitive determinant of choice. People may have various food-related goals, such as to save money or seek pleasure, which are often made more salient and compete with the importance of health considerations (Förster et al. 2007; Papies 2016b).

All these factors provide an opportunity for choice architects to improve diets by making health aspects more salient in the food-choice environment (Papies 2016a). Hence, reminding people about health at the point of purchase, e.g., in a supermarket, a canteen, or a restaurant, holds potential as a policy tool. Directing people's focus towards health can help by interrupting or redirecting automated behavioural responses and prioritizing health aspects when they reflect upon different characteristics of food choices.

Making the aspect of health more salient can be achieved through the use of large and colourful labels that, in addition to providing factual nutritional information, can activate health goals. These different mechanisms are difficult to disentangle in field experiments and therefore require more in-depth analysis in a controlled environment.

Going beyond food labels, several studies have tried to support consumers in the moment of decision-making by reminding them about the health aspects of their diet through various means. fMRI data show that simple health messages, e.g., "high in fat," can influence consumer choice by engaging specific neural systems in the decision-making process without affecting people's conscious valuation (Grabenhorst et al. 2013). Yet, a recent review of salience nudges in food and beverage choices found mixed evidence regarding the effectiveness of such interventions (Wilson et al. 2016). Interventions that combined different mechanisms showed overall more promising results. However, Wilson et al. (2016) consider only studies that self-identify as using nudges, which might lead to significant omissions.

Specifically looking at self-service settings (Skov et al. 2013) and worksite policies (Kahn-Marshall and Gallant 2012), two reviews find that some interventions providing health information in the form of health signs and labels at the point-of-purchase can increase healthy food choices. Such positive results were echoed for dietary choices in universities (Deliens at al. 2016; Roy et al. 2015). However, evidence for the use of point-of-purchase messages to increase vegetable sales was found to be insufficient for school settings (Nørnberg et al. 2016). The only study using point-of-purchase messages included in this

review, showed that some fruit and yogurt sales increased during the intervention period, while vegetables sales remained unaffected (Buscher et al. 2001). Summarizing evidence for point-of-purchase interventions in supermarkets and grocery stores, Escaron et al. (2013) find existing evidence to be insufficient. Rather, combining point-of-purchase interventions with other promotions or increase in availability seems to be more effective. A similar conclusion was reached after reviewing interventions aimed to increase healthy choices at vending machines. While there was limited evidence for the effectiveness of health claims, increased availability was shown to be most effective (Grech and Allman-Farinelli 2015).

Recent meta-analyses of labels with "low in fat/sugar or light" found mixed results where effects varied among descriptors, and the authors concluded that more evidence is needed (Shemilt et al. 2017). In contrast, a meta-analysis of general health claims by Kaur et al. (2017) concluded that health claims have a substantial effect on food choice, increasing choice of such foods (claiming to be healthy) up to 75%. Yet these results are mainly driven by lab experiments, and the meta-analysis raises caution regarding high study heterogeneity and possible publication bias (Kaur et al. 2017). Even though results from real-life settings were much smaller in magnitude, the health claims consistently affected food choice.

Interventions can address consumers directly and, for instance, add phrases such as "Are you also watching your weight?" to a restaurant menu. People exposed to the reminder messages significantly chose more of the low-calorie foods (Papies and Veling 2013).

Priming

Interventions that aim to increase salience are closely related to the priming literature (e.g., Doyen et al. 2012). Priming refers to the psychological phenomenon that people become more aware of, react to, and recognize objects more rapidly when they have been exposed to related cues or stimuli beforehand. This could be words that are just semantically related, but priming

can also activate long-term goals that lead to an inhibition of goal-conflicting behaviour and thereby increase self-control (e.g. Förster et al. 2007; Forwood et al. 2015). Hence, health priming does not necessarily require explicit messages or cues related to food. People might be nudged towards healthier choices by conscious or subconscious priming of health-related constructs or activation of health goals at the point-of-purchase (Papies 2016b).

Priming might be achieved with visual cues, smells, or other sensory stimuli, which could include the salient positioning of typical healthy food items. Given the definition used by Wilson et al. (2016), results of priming nudges to foster healthier food choices have been mixed. Several studies not included in the review by Wilson et al. (2016) show some more promise of priming interventions and find reduced consumption of unhealthy foods and a lower energy intake (Boland et al. 2013; Buckland et al. 2013), as well as increases in the consumption of healthy foods (Gaillet et al. 2013; Hollands et al. 2011).

However, in some studies, the effect of priming is limited to certain subpopulations. For instance, people on a diet are more likely to react to health primes than people without the intention to eat healthier (Buckland et al. 2013; Coelho et al. 2009; Forwood et al. 2015). This is in line with the assumption that priming works through activating long-term goals, such as to eat healthier. To influence behaviour, the prime requires the existence of an individual health goal that can be activated in the moment. This is consistent with two recent meta-analyses of food unrelated priming studies (Shariff et al. 2016; Weingarten et al. 2016a, 2016b). For instance, Buckland and colleagues (2013) find that only dieters will change eating habits when primed with a fresh orange compared to chocolate. However, a negative relation between food cues (smell of cookies) and later consumption was found for dieting participants in another study. Exposure to the smell of high-caloric food led to a reduction in consumption of the unhealthy alternative, compared to a control group (Coelho et al. 2009). Other studies also find that health cues increase healthier choices even in the absence of an explicit goal to eat more healthy (Hare et al. 2011).

Priming effects have also been found to alter dietary choices by showing pictures of potential negative health outcomes. When exposed to such adverse pictures (similar to the shocking pictures now used on cigarette packages in many countries worldwide), people had a more negative attitude towards snacks shortly after the exposure, and they were more likely to choose fruit rather than an energy-dense snack food (Hollands and Marteau 2016).

Social Norms

The way health messages are designed can benefit from additional behavioural insights. For instance, social norms can influence individual food choices because they provide an implicit code for appropriate behaviour in a given context (Higgs 2015). People we dine with or the waiter who serves us provide a social reference point that can lead to increased consumption *or* healthier choices when compared to eating alone (Döring and Wansink 2017). Such social norms can be activated through health messages about other people's behaviour by, for instance, informing people shopping in a supermarket that "in this store, most people choose at least five pieces of fruit and vegetables" (Payne et al. 2015). A recent meta-analysis concluded that information about eating norms has an impact on food choice and quantity eaten, which can be a useful tool to promote healthier diets (Robinson et al. 2014a). For instance, one study compared the effect of different health messages to increase fruit and vegetable consumption: A message simply highlighting the health benefits of more fruit and vegetable consumption was less effective than a message using social norms stating that most peers actually consume a lot of these food products (Robinson et al. 2014c).

However, not all social norm-based interventions studied were able to increase healthy choices (e.g., Pliner and Mann 2004). The success of many interventions was conditional on individual characteristics such as self-control (Salmon et al. 2014). A review on mediating effects of the impact of other people's behaviour on individual food choices showed stronger

effects for people we like or relate to, but lower effects for healthy snacks and during meal sessions such as lunch (Cruwys et al. 2015). Beyond the manipulation of social norms, many studies find people to generally eat more when in company (Herman 2015).

Using Healthy Defaults

The power of setting a default choice in behavioural policy was popularized through a public debate in the case of organ donations (Johnson and Goldstein 2003), and it gained further prominence in the debate on switching energy providers (Sunstein and Reisch 2013). Setting default options can also influence individual food choice, which is predominantly observed in fast-food restaurants (Loewenstein et al. 2007). Closely linked to risk aversion and the endowment effect (Kahneman et al. 1991), people systematically prefer the status quo and are reluctant to actively change or "downsize" their meal; the default option of a food portion can play a powerful role in decision-making (Johnson et al. 2012). Defaults additionally convey a socially appropriate eating norm and signal individuals as to the "normal" thing to choose.

The choice of defaults may hence be part of food companies' strategy to increase sales, but it also offers an opportunity to foster healthier food choices. However, empirical evidence for default effects remains scarce in food choice, and we did not identify a review article specifically devoted to food defaults. Therefore, we provide an exemplary overview of existing research and tested strategies in the field of food defaults, but more research is certainly needed to inform policy-making (Vetter and Kutzner 2016).

The impact of changing the default option of food choices has been predominantly tested in the composition of combined menus, usually including a beverage, side dish, and a main course (e.g., Anzman-Frasca et al. 2015). When food is not sold in combined meals, the use of positioning or portion size can frame certain food items as a quasi-default choice, as people have to opt out of the larger portion and specifically request a smaller meal (Thorndike et al. 2012).

Even though few studies have evaluated the effect of changing defaults in menu compositions, existing evidence shows that these interventions are able to change food choice. Among these studies is the work of McCluskey at al. (2012), who conducted a field experiment changing the default side dishes in fast-food restaurants; this study showed a decline in sales of the unhealthy options. The mere change of defaults led to a significant reduction in the unhealthy dessert option (2% each intervention month) but did not significantly decrease sales of the unhealthy main dish. Additional advertisement of the new "healthy choice" after six months led to a small but significant decline (0.8% each intervention month) for both food items. Another study analysing the change of defaults in McDonald's Happy Meal® showed that reducing portion size of fries and adding apples as a standard side dish did reduce the overall calories of the meals sold and did not lead to higher caloric choices for the main course or beverage (Wansink and Hanks 2014).

Sales data from Disney World's change of default beverages and side dishes in children's menus suggest that about two-thirds of the studied kids accepted the healthier menu composition (Peters et al. 2016). The stickiness of defaults seems to be stronger in fast-food restaurants than in more classical sit-in restaurants. A similar study conducted in sit-in restaurants finds mixed results regarding a change of default in children's meals. Even though the 40% of customers who stuck with all default items after healthy changes had been applied significantly reduced their calories, total average calories were not significantly reduced by the change in defaults (Anzman-Frasca et al. 2015).

Changing the Physical Food Environment

When consumers make purchase decisions they are subject to the arrangement of items and "seemingly irrelevant factors" (Thaler 2015) that do not directly aim to raise health awareness yet still influence choices. The design of the physical environment by altering placement and/or improving convenience or ease of use has been studied in the field of marketing and

strongly guides today's in-store and restaurant design. On the one hand, people do not like to put extra effort into bending down to the lowest shelf or reaching far into the back. On the other hand, items placed at eye level and on top of a restaurant menu are more salient to the consumer, and often just because of this positional effect these items become the preferred choice (Bucher et al. 2016; de Wijk et al. 2016). In restaurants and self-service settings, choice architecture is not limited to positioning of food items and includes actual portion size, size and shape of dishware, as well as colour and variety of the foods served (Wadhera and Capaldi-Phillips 2014).

Additionally, two earlier studies by the Cornell Lab (Just et al. 2008) showed that making healthier choices more convenient by prohibiting debit card payments for unhealthy alternatives (and selling these items only to cash-paying customers) increased the selection of healthy foods.

Positioning

A recent literature review reveals that 16 of the 18 experiments found prominent positional change to positively influence food choice (Bucher et al. 2016). Based on these findings, the use of positioning has the potential to help people adhere to dietary guidelines. However, current research has not yet identified the most efficient way to do so. For example, it is still unclear whether putting healthy food in a better position or putting unhealthy food in a worse position creates the larger effects. That such nuanced differences might be important was demonstrated by a recent study showing that people systematically increased the choice of healthy foods when these foods were presented on the left side of an unhealthy choice, while a reversal of the positioning did not boost unhealthy choices (Romero and Biswas 2016). Also, the strength of the positioning effect is found to be heterogeneous and to depend on the type of manipulation and the magnitude of the change (Bucher et al. 2016; Wisdom et al.

2010). Considering only studies altering the position, the meta-analysis by Broers et al. (2017) showed an overall positive effect of preferred positioning on fruit and vegetable choice (d = 0.39).

Some studies, however, fail to find differences in consumer choice following a change in positioning. If purchasing decisions are mainly driven by habits or if people have strong preferences, as in the case of bread, for instance, placing healthier whole-grain bread first in the walking direction of a supermarket aisle has made little to no difference in sales in an experimental field study (de Wijk et al. 2016). According to Levy and colleagues (2012), effects vary with the type of change but seem constant across different subpopulations. For instance, placing healthy beverages in a more prominent position increased choice, independent of ethnicity and socio-economic group. Even though more research has to identify the effectiveness and efficiency of such nudges on a broad scale, current evidence suggests that strategic positioning in the sense of salience, availability, and ease of access does influence consumer choice.

Presentation

In addition to altering the position of food items, changes in the way the food is presented and selected affect the perception of portion size, consumption, and satiation. Evidence that visual cues play an important role in food choice was famously provided by studies that tried to remove visual feedback by having participants eat in the dark or from a self-filling bowl. Both settings were associated with increased consumption (Scheibehenne et al. 2010; Wansink et al. 2005).

Food choices are subject to a variety of visual cues, and it is important to correctly distinguish among them. In addition to manipulating the actual portion size that determines the amount (i.e., weight and volume) of the food served, choice architects can: change the

container size and shape (e.g., plate size and glass shape); make explicit reference to the size of the package or the plate the food is served on (e.g., "Grande"); or vary the granularity of the food while keeping the amount constant (e.g., one large piece vs. ten small pieces). One review found most of the visual aspects tested to affect food consumption (Wadhera and Capaldi-Phillips 2014). However, each of these variations has its own effect on the perception of a food item or portion and must be considered in order to avoid confounding study results (Zlatevska et al. 2014).

The influence of plates can be partly explained by the so-called Delboeuf illusion, which holds that objects are judged in relation to other objects. Therefore, equal amounts of food seem larger when served in smaller containers (English et al. 2015).

However, Benton (2015) finds the overall evidence to be inconclusive, as several studies altering plate size find little to no effect (Rolls et al. 2007; Shah et al. 2011). This sceptical view was echoed by two systematic reviews concluding that current evidence does not support obesity interventions based on alterations of plate size (Libotte et al. 2014; Robinson et al. 2014b). Additionally, Skov and colleagues' (2013) review determined that interventions altering container size and cutlery provide inconclusive results in self-service settings. A recent review claims to have resolved the puzzle of mixed conclusions from previous reviews regarding plate size: Holden et al. (2016) suggest that the effect of plate size depends on the study design. While varying plate size had no effect on consumption if portion size was held constant, smaller plates had substantial effects when food was self-served (Cohen's d = 0.70). This implies that portion size is likely to mediate the effect. Participants unaware of being part of a food study also showed a stronger response to alterations in plate size. Overall, the authors estimate that on average, doubling the plate size will lead to a 41% increase in the amounts self-served and consumed. Based on this observation, food purveyors might consider removing the trays from buffet cafeterias, as large empty tray space might invite consumers to take more and consequently eat more or increase food waste. However, in

one study removing the trays not only reduced the quantity of choice, it also affected food quality. This study, based on university cafeterias, found that students without trays were 18% less likely to take a salad (Wansink and Just 2015) .

The perception of portion size is subject to additional systematic biases: People tend to judge food amounts more by the vertical than by the horizontal dimension, meaning that, for example, the volume of a beverage is perceived as greater when presented in a tall and narrow glass than in a short and wide glass with equal volume (Benton 2015). This phenomenon was also found for different shapes of food presentation: Equal amounts of food were perceived as larger when served in triangles compared to squares, with food served in circles being judged the smallest (Krider et al. 2001).

A narrative review of strategies to control portion size finds that size and form of glasses, plates, and also utensils can influence the dietary intake of children (Robinson and Matheson 2015). Among adults, larger dishware and serving cutlery can not only result in more consumption but also food waste (Wansink and Van Ittersum 2013). A study by Mishra, Mishra, and Masters (2012) highlights the importance of the study setting: While larger forks led to more food intake in their field study, people with larger forks ate less in the laboratory.

Hollands et al.'s (2015) Cochrane review on the effect of environmental conditions on food choice and consumption suggests that an overall reduced exposure to larger-sized food portions, packages, and tableware could reduce average daily energy consumed from food by between 144 and 228 kcal among UK children and adults.

If an edible item is not amorphous, such as soup, additional misperception arises from the granularity of the food. Two slices of pizza are perceived as a larger portion than one piece with double the size (Benton 2015; English et al. 2015). However, the relationship to calorie consumption is not that clear-cut, and various studies remain inconclusive (English et al. 2015). One recent canteen field study featured two identical serving tables with both brownies and apples, placed at separate locations of the conference venue. While higher

granularity (i.e., smaller servings) reduced the consumption of brownies, the consumption of apples increased by 83.9% by slicing them in small pieces during the intervention (Hansen et al. 2016).

Portion Size

The link between portion size and consumption is essential for mediating the effect of many behavioural interventions. If people would strictly follow internal cues and if eating behaviour would be regulated by feelings of satiety and hunger, the relationship between serving size and consumption would be insignificant. Therefore, defaulting people into buying smaller portions or promoting more fruit and vegetable purchases would have little effect on actual consumption. However, there is a strong consensus that external conditions do affect food consumption (Steenhuis and Poelman 2017), with some researchers arguing for a dominating role when compared to internal conditions (Benton 2015; Herman and Polivy 2005). Many short-term studies with various food items and in various environments make a strong case for the link between portion size and energy intake in adults and children alike (English et al. 2015; Osei-Assibey et al. 2012). Based on a meta-analysis, the average effect of doubling portion size on actual consumption is found to be 35%. However, the effect is found to diminish with the initial size of the portion and seems to be smaller for children, people with higher BMI, women, and non-snack food items (Zlatevska et al. 2014). In one long-term study, individuals were randomly assigned to different lunch-box sizes (400, 800, 1,600 kcal). The results show that the largest portion size led to a significant weight gain over six months (French et al. 2014).

The mechanisms behind the link of larger portions and increased consumption are not yet fully understood (English et al. 2015; Steenhuis and Poelman 2017). Presentation of a certain portion size might signal an “appropriate” amount to eat and provide an implicit social

norm, which people tend to follow (Benton 2015). The importance of such an anchoring effect has been tested in several studies: One study (Marchiori et al. 2014) anchored participants with imaginary scenarios and found that they estimated their own consumption as lower when presented with a low anchor. Also, large portion names (such as "double-size") can lead people to leave more food on the plate compared to smaller-sounding names, holding portion size constant (Just and Wansink 2014). However, a similar study (Ueland et al. 2009) showed that mere information about portion size had little effect on consumption. Treatment groups received the same amount of food but were informed that they had received either a half, a full, or one and a half portions. All participants had the opportunity to add food to their plate, but results showed no differences in total calories consumed and the feeling of satiety. Similarly, Brunstrom and colleagues (2012) found little impact of perceived consumption when hunger was assessed directly after the meal. In their experiment, participants consumed 300ml (500ml), with half of the group being informed that they actually consumed 500ml (300ml), leading to a 2x2 design. Two to three hours later, however, people's feeling of hunger was more determined by their perception than their actual consumption.

One mediating factor for the link between portion size and consumption might be found in actual bite size, which increases with larger portions (English et al. 2015). Eating the same amount of food with larger bites reduces the direct oral exposure. As people show a temporarily reduced liking of certain flavours due to intense exposure (sensory-specific satiety), this effect is less pronounced when taking large bites and could hence increase consumption (Benton 2015; Herman et al. 2015). However, portion size is found to have little impact on the biting frequency of eaters (English et al. 2015).

Food Variety

In real-life settings, a meal often consists of different components (within-meal variety) and is generally only one part of the daily diet where different meals can vary in flavour and consistency (across-meal variety). Increasing both types of variety is associated with higher energy intake, which can be explained by a reduction in sensory-specific satiety. Already the perception of variety of food beyond mere taste experience, by artificially changing colour, has been found to increase consumption (Wadhera and Capaldi-Phillips 2014). Additionally, eating palatable foods can lead to a hedonic escalation, where each bite becomes more liked than the previous one, which could help explain a tendency to over-consume this food (Crolic and Janiszewski 2016). Meanwhile, increasing the variety in salad bars seems to be a promising strategy to boost vegetable consumption (Hendren and Logomarsino 2017).

In self-service settings, most people tend to plan their meal and choose the portion size they want. This is important since people show a general tendency to empty their plate. Therefore, individual expectation about the potential satiation of a meal is of high importance (Fay et al. 2011). Results of one study indicate that expectation about satiation is a main determinant of chosen portion size, rather than expected liking (Brunstrom and Rogers 2009). However, there are substantial differences in satiation and satiety expectations for different foods given the same number of calories. The same research team (Brunstrom and Rogers 2009) showed that foods with higher caloric density provide a lower expected satiety, which might explain the selection of larger portions. The expected satiety can, however, be revised and relearned over time (Forde et al. 2015).

Incentivize Healthier Choices and Pre-planning of Food Choice

The fact that people make unhealthy food choices that are not in their own long-term best interests can, at least partly, be ascribed to a disconnect between food choices and related

health outcomes later in life. Many people overvalue enjoyment in the current moment and are overly optimistic about their future or neglect the possible adverse consequences. This so-called *present bias* relates to the economic theory about overly discounting the future benefits when faced with a trade-off between now and later (Laibson 1997; Richards and Sindelar 2013). Regarding obesity, a positive correlation between BMI and higher temporal discount rates has been shown in several studies (Golsteyn et al. 2014; Zhang and Rashad 2008), but a recent review concludes that current evidence regarding this link remains inconclusive (McClelland et al. 2016). The authors emphasize that individual discount rates seem to vary in obesity due to a number of factors, such as current metabolic state (hunger and satiation).

In the search to overcome the misjudgement of long-term costs and short-term benefits, researchers have tried to link healthy choice with immediate rewards. The use of incentives differs from mere changes in the price of the product since such incentives can well be non-monetary and intangible or of minimal value, and they work by providing immediate positive feedback (e.g. small gifts, participation in a lottery). Therefore, the use of incentives to foster healthier food choices goes beyond increasing the mere (monetary) value of the healthy choice. However, a few review papers have studied the effect of price changes primarily in the context of multi-component interventions and not incentives by themselves. Even though this does not qualify as genuine behavioural intervention because it significantly changes the economic incentive, we briefly present their results here.

A recent stream of literature focuses on children eating in schools or after-school programmes. Different incentives were used to promote healthier food choices, such as making a healthier choice of two alternatives (List and Samek 2015) and choosing (Belot et al. 2016) or eating more fruits and vegetables (Just and Price 2013; Loewenstein et al. 2016). The incentives in these studies varied among toys (List and Samek 2015), stickers (Belot et al. 2016), and small monetary incentives (Just and Price 2013; Loewenstein et al. 2016). Some of these interventions used additional behavioural insights and varied the incentive structure by

applying different framings or introducing a competitive element to improve effectiveness (Belot et al. 2016; Just and Price 2013). Incentives were in place between one and five weeks, and virtually all interventions were able to improve healthy food choice and consumption. Effect size varied among studies. Loewenstein et al. (2016), for instance, found a monetary incentive of 25 US cents to double the share of children eating a serving of fruit and vegetables during lunch. Follow-up studies showed different results. While some studies found effects up to two months even after taking away the incentive (Loewenstein et al. 2016), others could not observe differences six months afterwards (Belot et al. 2016).

A series of studies by Reimann et al. (2015) showed that modest incentives can lead to choices of smaller portion sizes among children and adults. Offering people the opportunity to trade their initial choice of a full-size meal for a half-size portion combined with different types of incentives (e.g., gift cards or lottery tickets) led a significant number of people to choose the smaller portion. However, the effect-size in this field study was substantially lower compared to previous lab results. General price incentives for healthier foods are often part of multi-component interventions; results indicate that price changes are an effective instrument to foster healthier choices (Escaron et al. 2013; Grech and Allman-Farinelli 2015; Hendren and Logomarsino 2017).

Overall, directly incentivizing healthier eating choices has received less attention in the literature, while incentives in weight-control programmes and healthy behavioural-change programmes have been studied widely. One review by Purnell et al. (2014) concludes that 11 of the 12 studies, including simulations, observational studies, and randomized trials, find a positive but short-term effect of financial incentives on different dietary-related outcomes such as weight loss and food choice. Mantzari and colleagues' review and meta-analysis of financial incentives (2015) also finds overall positive effects on health behaviour, including weight loss and healthy eating; however, there was little evidence for sustained effects in the post-incentive period. With the exception of one study (Jeffery et al. 1998), the lack of long-

term effects was echoed in another review by Mitchell et al. (2013), who suggested that financial incentives can increase physical exercise only for six months maximum.

An alternative way to overcome present bias is to pre-plan meals and make food choices in advance – a strategy using elements of voluntary self-binding. This approach has been famously used in the "Save More Tomorrow" programme that aimed to increase pension contribution by pre-committing to save further income raises rather than taking from current income (Thaler and Benartzi 2004). Ordering food in advance and in a non-hungry state without exposure to appealing smells might facilitate food choice without overvaluing present indulgence and could better incorporate health concerns.

In addition to the mechanism of *temporal discounting*, a recent conceptual review identified two other factors that contribute to people's inability to stick to a healthier diet (Appelhans et al. 2016): attention bias and the hot-cold empathy gap. Complementing the so-called "homeostatic system" that regulates energy balance, the "reward-based system" is responsible for cravings that motivate behaviour with the aim to receive highly rewarding foods, which are often calorie-dense. Such cravings can be triggered by food cues that activate the reward-sensitive brain areas, making it difficult to focus attention away from the unhealthy but rewarding food item. Being in a hungry state generally increases such an *attention bias*, particularly if the decision is about food. However, hunger is only one of the many visceral factors affecting human judgement; people feeling tired are more likely to rely on heuristics and automated responses (Loewenstein 1996). Further, being in a "hot" state of impulsiveness increases the tendency to choose more rewarding food (Cameron et al. 2014; Goldstone et al. 2009; Tal and Wansink 2013). When in a neutral "cold" state, people generally fail to anticipate their own susceptibility to reward cues during the "hot" state. This so-called *hot-cold empathy gap* has implications on people's accurate anticipation of their ability to resist temptation (Appelhans et al. 2016).

Hence, people are predicted to make healthier choices in a "cold" state for meals in the not-too-near future. A study investigating this effect among school children found that 15% fewer students chose the healthy alternative when ordering in the service line compared to a control pre-ordering in the morning (Hanks et al. 2013). A previous study led by Just et al. (2008) showed less success when asking students to pre-order their meals. With the exception of brownies, they even purchased fewer of the healthy items compared to students making their decision at the point-of-purchase, suggesting that the effect of pre-ordering might be food-specific. Additionally, the effect of hunger on food choice might strongly depend on the environment people are exposed to. For instance, Cheung et al. (2017) showed that hungry people are more likely to rely on automated processes and, therefore, might be more sensitive to the choice architecture. In their study, a nudge using social norms showed stronger effect in hungry than in satiated individuals.

Positive effects of pre-planning meals have also been found in weight-control studies (Rock et al. 2010), but the general approach has received less attention in the field. Au et al. (2013) review the literature to estimate the cost-effectiveness of pre-commitment strategies in fostering healthier food choice, weight loss, and health outcomes among overweight adults. Using Standard Behavioural Therapy (SBT) combined with sticking to a shopping list led to a 6.9-kg reduction in weight after one year (and exceeded the "SBT only" group by 3.3 kg on average). Au et al. (2013) estimate costs of 166 British pounds in 2010 prices for gaining one quality-adjusted life year (QALY),[8] which is a huge savings compared to the cost of 20,000 to 30,000 British pounds per QALY estimated by the UK National Institute for Health and Care Excellence (Raftery 2014).

- Insert Table 2 about here -

[8] A QALY is defined as one life year in full health, often used to compare cost-effectiveness of different interventions in health economics (for details see Raftery 2014; Sassi 2006).

Discussion

A behavioural approach to policy-making incorporates a more holistic understanding of human decision-making but comes with a number of caveats. Going beyond the model of a rational agent creates a much more complex interplay of research fields spanning different disciplines. Such collaboration has to overcome a number of differences: Researchers speak different field-specific "languages," and some disciplines are historically further away from providing research results with direct policy implications. To enrich our understanding of food choice and translate important findings into policy, a coordinated effort is required to build bridges between those fields of research.

Summarizing, understanding, and connecting the literature from all relevant research fields is beyond the scope of any single review due to the immense complexity of food choice. The present study is hence limited to an attempt to condense the current state of behavioural interventions in food choices and to provide an enriched view of some key underlying mechanisms from the various disciplines that contribute to narrowing the existing research gaps. We identified 39 reviews focusing on interventions or manipulations in the choice architecture that aimed to alter individual food decision-making. Studies substantially differed in quality and setting, which limited the ability to draw clear conclusions regarding "What works where and why." Against this background, we recommend some caution with the interpretation of our findings, which are discussed in the following.

With few exceptions (e.g., Campos et al. 2011; Littlewood et al. 2016), there appears to be a consensus among the reviews that the mere *provision of caloric information* is unlikely to have strong effects on individual food choices (Cantu-Jungles et al. 2017; Kiszko et al. 2014; Long et al. 2015; Nikolaou et al. 2015; Sacco et al. 2017; Swartz et al. 2011), or results are inconclusive (Bleich et al. 2017). Two plausible explanations emerge from the literature. First, *insufficient attention* to the caloric information might hamper the effectiveness. This is in line with the observation by various reviews that the results from controlled lab environments show generally stronger effects than studies conducted in real-life settings (e.g., Cantu-Jungles et al. 2017; Long et al. 2015; Sacco et al. 2017), where many distractions might reduce attention to the food choice. While not all lab studies have positive results (e.g., Bleich et al. 2017), a sub-groups analysis in Nikolaou et al. (2015) highlighted that labels only have a significant effect for individuals who have actually noticed them. The limited evidence in favour of nutritional facts might be attributed to the way they are presented, which could merely create an insufficient degree of attention to affect choice. More salience can be achieved with front-of-package labelling and colourful logos, which brings us to the second plausible variable: *ease of consideration*.

While being recognized remains a necessary condition, evidence also points to better results when nutritional information is simplified, supported by contextual information, and directive (e.g., Cecchini and Warin 2016; Fernandes et al. 2016; Hawley et al. 2013; Sinclair et al. 2014). Such benefits are not clearly identified by all reviews (e.g. Bleich et al. 2017) and seem particularly limited for children and adolescents (Sacco et al. 2017). A lack of motivation to use nutritional information is an important barrier for overall effectiveness (Grunert et al. 2010). Increasing health considerations, though the nutritional label itself or complementing interventions (further discussed below), might help to mitigate this issue (Storcksdieck Genannt Bonsmann and Wills 2012).

Concerning population characteristics, people with higher socio-economic status (SES) seem more likely to benefit from caloric information (e.g., Campos et al. 2011), potentially because of a positive link between nutritional knowledge and the use of point-of-purchase information (Miller and Cassady 2015; Spronk et al. 2014). Another divide might stem from different restaurant settings, where classical sit-in restaurants and coffee shops seem to provide a better environment for calorie information to be effective, when compared to fast-food restaurants (van Epps et al. 2016). The latter is more likely to be frequented by individuals with a lower SES. It is, however, not fully clear if these findings are related to different audiences, the choice setting, or alternative mindsets when entering a fast-food restaurant to specifically obtain a high-calorie "treat" (Bleich et al. 2017).

The overall evidence for interventions *increasing health salience* and *communicating healthy social norms* must be described as mixed. Reviews supporting such interventions are generally focused on specific settings (e.g., Deliens et al. 2016; Hendren and Logomarsino 2017; Roy et al. 2015) and rarely show large and robust effects on food choice. Other reviews find the existing evidence to be insufficient or inconclusive (e.g., Escaron et al. 2013; Grech and Allman-Farinelli 2015; Hillier-Brown et al. 2017; Wilson et al. 2016). Salience through point-of-purchase signs and messages is often part of multi-component interventions, and in combination with increased availability, presentation or price reduction effects on healthy choices are larger (e.g., Escaron et al. 2013; Kahn-Marshall and Gallant 2012). Such interventions limit the assessment of their individual contribution (Allan et al. 2017). More focused reviews, however, show that specific approaches can be effective. Robinson et al. (2014a) conclude that social-norm messaging affects food choices. Kaur et al. (2017) find that health and nutritional claims can have a substantial effect on dietary choices, even though effects differ among product categories.

So far, no review has focused on the effects of *healthy food defaults,* and more studies are clearly needed. Defaults are widely considered to be one of the most powerful behavioural policy tools and should therefore be explored in the context of food choice. While not derived from an exhaustive review of the literature, the limited evidence presented here demonstrates generally positive – however context-specific – results (e.g., French et al. 2014; McCluskey et al. 2012; Wansink and Hanks 2014). Peters et al.

(2016) show that effects tend to be stronger in fast-food than sit-in restaurants. As we can only speculate about explanations for why sit-in restaurants might decrease the stickiness of healthy defaults (e.g. stronger motivation to indulge, better cognitive reflection of the food choice or longer exposure to hedonic cues within the choice environment), more research is needed to understand when healthy defaults work best.

Various *physical changes* in the design of food choices seem to consistently affect the quality and quantity of food chosen. While the specific mechanisms differ among the surveyed studies – from changing the effort to obtain food, the perception of healthiness and quantity, and the sensation of foods (i.e., flavours or oral processing) before or during a meal – most results suggest that such interventions could effectively alter food choices. Studies reviewing changes in food positioning, dishware, portion size, and food variety find a meaningful influence on food choices (Broers et al. 2017; Bucher et al. 2016; Holden et al. 2016; Hollands et al. 2015; Roy et al. 2015; Wadhera and Capaldi-Phillips 2014; Zlatevska et al. 2014). Still, a relevant number of reviews could not support such an overall conclusion (Libotte et al. 2014; Robinson et al. 2014b; Skov et al. 2013).

This might not be surprising since the original literature, particularly from field studies, is often of poor methodological quality and highly heterogeneous in context and population. The fact that effectiveness of interventions varies among different study designs is most elaborately shown with regard to the portion-size effect. Results seem to depend on the type of food, the way food is selected, and whether the study design is overt or not (see Holden et al. 2016; Lycett et al. 2017; Robinson et al. 2014b), which makes it difficult to draw general conclusions for policy-makers.

The review of *healthy incentives and pre-planning* was hampered by the lack of focused reviews and the unclear distinction between point-of-purchase incentives and mere price changes. As in the case of healthy defaults, we provided a conceptual overview of potential mechanisms and selected empirical results. The approach seems theoretically convincing and should receive more attention in the future. In particular, incentivizing healthier choices among children is a promising avenue that needs further testing over longer periods. An extended search for reviews incentivizing weight loss rather than food choice (Mantzari et al. 2015; Purnell et al. 2014) showed that persistent effects beyond the intervention period are rarely observed. This suggests that incentive structure might require permanent implementation rather than trying to achieve long-term behavioural change through one-shot interventions.

Where to Go from Here – Some Implications for Policy

Building on what we have learned from our review exercise, we offer three recommendations to better understand, coordinate, and promote behavioural policies fostering healthier food choices. These are: (1)

Define the level of evidence and create an adequate research environment. (2) Map the evidence in pursuit of better theory and understanding of conditions for effective behavioural policy. (3) Educate consumers about behavioural biases, heuristics, and behavioural policies.

Define the Level of Evidence and Create an Adequate Research Environment

Admittedly, advocates of behavioural food policy have the burden of proof that their approach to tackle the obesity epidemic provides a meaningful contribution. Even though recent evidence suggests a high cost-effectiveness of behavioural interventions in various areas (Benartzi et al. 2017), critics argue that the level of evidence in food choice is currently insufficient, particularly in terms of reducing actual obesity levels (Lusk 2014). This criticism is not limited to research aiming to inform behavioural policy – it concerns a larger problem in areas of psychology and consumer behaviour research raising the fundamental question whether published academic research is true (Ioannidis 2005; Laber and Shedden 2017; McShane and Gal 2017; Simmons et al. 2011). A good deal of the empirical research reviewed in this report is explorative, based on small samples and therefore prone to provide false-positive results (Gelman 2017; McShane and Gal 2017). This issue is not only linked to study design and statistical analyis, it is driven by a publication process that favours suprising and novel findings over replication. In light of the current "replication crisis," problems concerning publication bias, "p-hacking," reproducibility, and external validity of statistically significant study results have cast doubts upon existing theories or the entire sub-field of research. To approach this problem "one needs to push to reform scientific measurement, data analysis, communication, and the incentives to scientists" (Gelman and Geurts 2017).

Even though this criticism has irrefutable merit, it is important to understand that food choices are a particularly complex area for behavioural research. While public health policy is increasingly concerned with rising obesity levels, to date there is no overall consensus about the dietary components or behaviours that actually cause obesity (Bischoff et al. 2017; Casazza et al. 2013; Hill and Peters 1998; Lucan and DiNicolantonio 2015; Taubes 2013). Hence, if the effects of reducing caloric intake on obesity are unclear from a nutritional point of view, then the success of a behavioural intervention aiming to reduce calories cannot be adequately evaluated on its ability to change BMI.

Altering a specific choice architeture can be highly cost-effective but is likely to have only a small effect on food choice. Hence, even if obesity were caused by the mere overconsumption of calories, measuring significant changes in BMI might be difficult. A model of calorie imbalance estimated that a daily change of about 24 kcal (100 kJ or the equivalent of 2 ½ peanut M&Ms) would lead to a change in body weight of 1 kg. This change in body weight is achieved over an extended period of time, with only half of the effect achieved after one year, and 95% after three years (Hall et al. 2011). A reduction in

caloric intake of this magnitude does not seem unreasonable given the current level of existing evidence (e.g., 78 kcal reduction due to calorie labels; Littlewood et al. 2016). However, measuring this effect would require expensive long-term studies with a very large sample size – something that is usually out of reach for most academics. Hence, limited funding that results in small sample sizes increases the probablity of false-negative studies that are simply too underpowered to detect small reductions in BMI.

This raises the general question about the *level of evidence* that is required to justify governmental engagement in an area. For instance, many Western countries have introduced a minimum wage in the labour market, despite remaining uncertainty of its overall effect. While advocates emphasize that it improves the life of the less affluent, opponents highlight its potentially adverse effects on employment and job creation (e,g, de Linde et al. 2013; Doucouliagos and Stanley 2009; Schmitt 2013).

Even though a great deal of experience and expertise are found in academia, the need for more robust evidence requires an active engagement by governments in experimentation, as the current lack of appreciation for replication studies in the social sciences offers limited incentives for academics to fully engage this process. In some cases, public-private projects might provide the best approach to pilot-test tools in the real world.

In line with this question, reports by international institutions highlight the need for a more coordinated approach and provide guidelines on how to create reliable evidence from testing (OECD 2017; Sousa Lourenço et al. 2016). Hence, regulatory action does not constitute the implementation of perfectly robust policy tools but rather is part of the process of evidence generation. The implementation of local experimentation following global standards is a novel approach for most administrations that requires a certain capacity, know-how, and commitment. In the absence of an overarching theory, an empirically driven field has to ensure that progress is based on proper empirical work.

Public officials require support and training to participate in the process and contribute to smarter and more efficient health policies. When experimentation must be part of the policy-design process, following the idea of "test-learn-adapt-share," an environment that accepts failure is needed to avoid discouraging public employees from engaging in the process. The growing field of online food purchases and digital transactions creates enormous amounts of data that can help elucidate potential conditions and pathways of behavioural policy. Such data are often in the hands of private retail stores and might not be accessible to researchers.

Following the "health in all policies" framework of the WHO (2014), we need to foster knowledge and data creation that improve understanding of the determinants of food choice. Public schools and canteens require monetary and non-monetary incentives to engage in research collaborations and data collection, which should be already incorporated into public procurement contracts. Hence, our first recommendation to both academics and policy-makers is to engage in a more intensive knowledge

exchange with each other. The aim is to identify barriers of acceptance and to discuss and clarify requirements such as the level of needed evidence *ex ante* to governmental activity. Based on this debate, governments need to provide sufficient research funding, and for actors of practice, researchers need access to real-life settings.

Map the Evidence in Pursuit of Better Theory and Understanding of Conditions for Effective Behavioural Policy

It is essential to understand more about the conditions under which behavioural interventions alter food choices. This refers not only to the main effect of a specific intervention but also to the conditions that lead to potential side-effects and adverse behaviour. A recent review compared different types of healthy-eating interventions regarding their impact on inequality between socio-economic status levels. While interventions targeting the individual (e.g., providing education or counselling) seem to widen inequality, targeting the external environment (i.e., changing price or placement) predominantly narrowed differences along the socio-economic gradient (McGill et al. 2015).

However, other studies find individual response to specific interventions to depend on several factors, such as preference strength, socio-demographic characteristics, and the current mental and visceral states. Understanding the interplay of these factors with the choice architecture is crucial to create adequately targeted interventions (see Szaszi et al. 2018 for a recent review). For instance, interventions based on health priming theoretically rely on (or should be at least amplified by) an existing goal to eat healthier, and the individual needs to know that product A is more in line with achieving this health goal than product B. Hence, both conditions require a certain level of motivation and knowledge that might differ within the target population. As obese men in the U.S. are less likely to be motivated to lose weight compared to women, we would expect a different response (Tsai et al. 2015). Similarly, knowledge about what constitutes a healthy alternative varies with socio-economic status (Spronk et al. 2014) and therefore might moderate the effect of the interventions (Forwood et al. 2015; Miller and Cassady 2015). Additionally, the effectiveness of the priming message itself could differ with socio-demographic characteristics, such as gender (Minas et al. 2016).

Even though there might be an innate preference for high-caloric food, preferences and expectations are partly learned from prior experience (Brunstrom and Rogers 2009). As these expectations and liking increase with familiarity, subtle nudges to shift to healthy foods might penalize people from households that rarely serve these foods, making it comparably more difficult to alter choices (Forwood et al. 2015; Pliner 1982). Such conditional effects might, on the one hand, explain the lack of effectiveness of some interventions, but on the other hand, they raise concern about heterogeneous treatment effects that potentially increase health inequality (McGill et al. 2015).

This *effect heterogeneity* might also apply to potential side-effects. Goal theory predicts that the fulfilment of the health goal should reduce goal importance in subsequent choices (Förster et al. 2007), which could translate into compensatory behaviour. Hence, highlighting the health aspect of a transparent nudge towards healthier food choices might not compromise the effectiveness within a choice setting (Marchiori et al. 2017) but could foster adverse side-effects. This is a reasonable concern, given that the perception of past meals seems to be an important determinant for hunger later in the day (Brunstrom et al. 2012; Crum et al. 2011).

Understanding these dynamics requires a *streamlined effort* to explore the conditions under which a specific behavioural policy becomes effective – an effort that could potentially benefit from a better use of theory (Marchiori et al. 2017) and collaboration with the natural sciences (Leng et al. 2016). Given the complexity of the research field, an important step towards robust evidence could be a coordinated effort to create an *evidence map* tracking the existing level of evidence and highlighting current research gaps (Miake-Lye et al. 2016). This requires collective agreement on a generally accepted definition and taxonomy of behavioural intervention, including mediating factors and standards for measuring them. We suggest that such an evidence map should be accompanied by a standard reporting practice (e.g., CONSORT statement),[9] as unsystematic reporting practices are common in the nudging literature and impair the effort to conduct meta-analyses (Allan et al. 2017).

Such evidence-mapping infrastructure should be constantly (automatically) updated, and this might be embedded in the academic publishing process. Such an endeavour was started in December 2017 by two French researchers (Romain Cadario and Pierre Chandon), who linked their meta-analysis to an online tool that allows other researchers a form of "live" updating.[10] This could provide insights for policy-makers as well as guide research to fill current gaps and help assess the contribution of each novel finding to the research field.

As another promising example, the "Human Behaviour-Change Project" started in 2016 with the aim to build an artificial intelligence system that constantly monitors relevant literature on behaviour change and extracts important information to help answering the big question: 'What behaviour-change interventions work, how well, for whom, in what setting, for what behaviours and why?'[11] A recent study that engaged in systematic interdisciplinary mapping of predictors of food choice (Symmank et al. 2017, p. 34) concluded that "the field [is] highly interdisciplinary [and] that the relevant knowledge on the mechanisms that guide food decision making is spread across publications from very different domains

[9] http://www.consort-statement.org/.
[10] https://insead.eu.qualtrics.com/jfe/form/SV_1ENmOXnDHtoYnkx.
[11] http://www.ucl.ac.uk/human-behaviour-change/about.

and with several (highly diverse) mental paradigms represented in domain-specific theories, study designs, and data. Therefore, future studies should try to link and integrate the perspectives of the different disciplines to paint a more realistic picture of the food decision."

We hence recommend that governments support such databases and evidence-mapping exercises financially and politically, and that researchers partake in such coordinated evidence hubs to help them grow, set standards, and become influential.

Educate Consumers about Behavioural Insights

This review provided evidence that individual food choice is subject to the choice architecture, and it also depends on the individual and the current visceral and mental states. Despite the common wisdom "I should not go food shopping when I am hungry," behavioural insights have mostly been debated within the research community. About 80% of U.S. adults blame primarily themselves for the rise in obesity (Lusk and Ellison 2013). It is unclear whether this attitude exists despite or because of the so-called *hot-cold empathy gap* (Appelhans et al. 2016), meaning that people overestimate their ability to self-regulate when answering a survey, or whether their responsibility includes the use of self-regulation strategies.

Overall, people seem to approve of nudges that support their effort to eat healthier (Junghans et al. 2015; Reisch and Sunstein 2016; Sunstein et al. 2017), but it is surely valuable and necessary to continue to educate consumers about these behavioural mechanisms and supply them with behavioural tools for self-regulation. For instance, individuals who are informed about the general tendency to underestimate the caloric content of food provide better estimates than those who do not receive such bias disclosure (Chandon and Wansink 2007).

There is increasing evidence that determinants of food choice such as preference and the feeling of hunger are, at least to some extent, externally determined. For example, translating common notions like "I don't eat these vegetables because I don't like them" to "I don't like these vegetables because I don't eat them" or "I bought this snack because I often get hungry" to "I feel hungry because I bought this snack (and placed it in a visible position)" might support individual ability to reflect on the influence of environmental factors. Such knowledge might empower consumers to use their market force and demand health-fostering environments from restaurants, employers, and the retail sector; it might also help mitigate the tension between individual responsibility and manipulation of environmental factors (Lusk 2014).

However, individual ability to self-regulate one's own environment to avoid self-control failure is likely to be related to socio-economic factors and might therefore not be a suitable approach for the whole population (McGill et al. 2015; Mullainathan and Shafir 2013). Also, communicating the observation that

a lack of cognitive control is commonplace bears the risk that people give up trying and actively reduce their efforts to execute self-control (Rogers 2017).

Nonetheless, we recommend health communication to help people integrate known biases in behaviour and perception of food consumption – as well as the implications for satiety and satiation – without reducing the role of individual agency. Such understanding might also increase individual willingness to regulate the surrounding food environment. Consumers can leverage their market power and demand health-promoting environments and options.

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Table 1: Five types of health nudges

Provision of information	Use of salience and social norms	Changes in the default	Changes to the physical environment	Incentives and pre-planning
The use of behavioural insights to improve the communication of nutritional knowledge and point-of-purchase information.	Interventions that aim to make health a salient aspect in the moment of decision-making.	Making healthier options the default choices.	Altering the location, presentation, and composition of food to foster healthier choices.	The use of incentives and pre-commitment to alter food choices.
Source: Adapted from Perry et al. (2015).				

Table 2: Summary of review articles

Study	Focus	Sample	Method	Results	I	S	D	P	T
Reviews on single type of intervention									
Bleich et al. (2017)	Consumer responses to numeric and modified calorie information.	Total: 53 studies,1976-2016. Setting: real-world: 27, controlled/lab/simulation: 21, change in restaurant offerings: 5.	SR	Given the lack of adequate studies, the authors cannot fully assess the effectiveness of calorie information. Some evidence suggests that effects differ between the type of restaurant, which generally tend to adjust their offerings towards caloric content. Whether contextual information increases use across SES requires more research.	x				
Campos et al. (2011)	Effect of nutritional information presented on pre-packaged foods on consumer use and dietary habits.	Total: 120 studies, 1976-2011. Designs: cross-sectional surveys: 96, experimental designs: 17, natural experiments: 7, longitudinal population-based surveys: 2.	SR	Labels are highly cost-effective and scalable. Effects are smaller for some vulnerable groups, and improvements in format might increase effectiveness.	x				
Cantu-Jungles et al. (2017)	Effect of restaurant menu labelling on calories and nutrients chosen.	Total: 14 studies, 1996-2014. Setting: real-world: 9, controlled/lab: 5.	SR & MA	No effect of menu labelling on calories ordered or consumed (including nutrients). Significant results only in the subgroup of laboratory settings.	x				
Cecchini and Warin (2016)	Impact of different food labels on choice and caloric intake.	Total: 9 randomized controlled studies, 2008-2015. Setting: real-world: 2, controlled/lab: 3, online: 4.	SR & MA	Individuals choose the healthier option from different alternatives 18% more often compared to the control groups without labels. Data for calorie reduction were insufficient. The MTL labels seem more effective compared to the GDA.	x				
Fernandes et al. (2016)	Influence of menu labelling on food choices in real-life settings.	Total: 38 studies, 1976-2013.	SR	Labels have mixed effects and the authors regard the current evidence as questionable and overall not effective. Effects differ among settings and simplified qualitative information, such as the MTL, seems most effective.	x				
Hawley et al. (2013)	Effects of front-of-package food labels on consumer decisions.	Total: 28 studies, 1982-2011.	SR	The MTL system has the most consistent support but requires further testing in different populations. The review suggests	x				

Study	Focus	Sample	Method	Results	I	S	D	P	T
				that a label should contain calorie information per serving and, daily caloric information and indicate nutrient levels as high, medium, and low.					
Kiszko et al. (2014)	Evidence on the effectiveness of calorie labelling at the point-of-purchase.	Total: 31 studies, 2007-2013. Setting: real-world: 18, controlled/lab: 13.	SR	The authors conclude that the large body of literature does not provide support for the effectiveness of calorie information in its current form.	x				
Littlewood et al. (2016)	Whether menu labels reduce energy selected, ordered, or consumed in real-world and experimental settings.	Total: 15 studies, 2012-2014 Setting: real-world: 7, controlled/lab: 5, online: 3.	SR & MA	The MA suggests that labels reduce the energy consumed (ordered in real-life settings) by 100 kcal (78 kcal). No publication bias was detected. Evidence also points to consumer learning from labels, which might lead to better dietary choices in other areas. Interpretive support and simplification can mediate barriers for utilization.	x				
Long et al. (2015)	The relationship between menu calorie labelling and calories ordered or purchased.	Total: 19 studies, 2008-2013. Setting: real-world: 9, controlled/lab: 6, online: 4.	SR & MA	Overall reduction of 18 kcal was mainly driven by laboratory studies (alone 58 kcal), with insignificant reduction of 8 kcal in restaurant settings.	x				
Nikolaou et al. (2015)	The effect of calorie labelling on calories purchased.	Total: 7 studies in real-world settings, 1990-2014.	SR & MA	The meta-analysis showed no overall significant effect (-6 kcal). However, for people who reported to have noticed the labels, a reduction of 125 kcal was estimated.	x				
Sacco et al. (2017)	The influence of menu labelling on child and adolescent calorie orderings in restaurant and cafeteria settings.	Total: 11 studies, 2005-2015. Setting: real-world: 6, controlled/lab: 4.	SR	While results from artificial settings suggest positive effects of menu labelling (order of less calories), effects are found to be limited in the real-world. The authors advocate the need for further studies to fully assess the benefits of interpretive over informative labels and the importance of socio-demographic factors.	x				
Sinclair et al. (2014)	Identify all controlled experimental and quasi-experimental studies that reported the effect of informative, contextual, or interpretive menu	Total: 17 studies, 1990-2013. Design: quasi-experimental: 7, experimental: 10.	SR & MA	Pooled data shows calories selected (consumed) were reduced by 43 (41). Descriptive labels only reduced calorie selected (consumed) by 31 (13) kcal, which was statistically	x				

Study	Focus	Sample	Method	Results	I	S	D	P	T
	labelling on calories selected or consumed.			insignificant. The provision of additional information reduces kcal selected (consumed) significantly by 67(81) kcal.					
Swartz et al. (2011)	Assess experimental or quasi-experimental studies comparing calories ordered between individuals provided with food labels and a control group.	Total: 7 studies, 2008-2011. Setting: real-world: 5, controlled/lab: 2.	SR	Only two of the seven studies found significant reduction in calories purchased. The evidence does not support the use of menu labels.	x				
Van Epps et al. (2016)	The impact of numeric calorie posting on purchases.	Total: 16 real-world studies, 2009-2015.	SR	Calorie postings have little effect in classical fast food restaurants but seem to be more effective in full-service restaurants or coffee shops. Stronger results in the latter setting might be explained by customer differences in SES.	x				
Robinson et al. (2014a)	Effect of social eating norms on eating behaviour.	Total: 15 studies, 2001-2014.	SR & MA	There is a moderate effect of social norm information on eating behaviour, suggesting that social norm messaging information might be a promising tool to increase healthy food choices.		x			
Bucher et al. (2016)	Effect of positional changes on food choice.	Total: 15 studies, 1976-2014. Setting: real-world: 12, controlled/lab: 3(4).	SR	All but one study found a positive effect of proximity or ordering on food choice, with magnitude difficult to quantify. The studies heterogeneity precluded a MA.				x	
Holden et al. (2016)	Effect of different plate sizes on food choice and consumption.	Total: 20 studies, 1996- 2014.	SR & MA	Effect of plate size differs between study designs. Studies comparing fixed portions on different plate sizes had little to no effect, while substantial effects are observed in self-service settings. Doubling plate size increased the amount consumed by 41%.				x	
Hollands et al. (2015)	Influence of different portion, package, or tableware sizes on food selection and consumption.	Total: 69 RCTs, 1978-2013.	SR & MA	People consistently consume more food and drink when offered larger portions, packages or tableware compared to smaller versions. Such interventions could reduce daily energy intake by 144 to 228 kcal.				x	
Libotte et al. (2014)	Effect of container size on energy intake.	Total: 15 studies, 2005- 2013.	SR	Distractions (present rather than absent), the type of container (bowls rather than plates) and the type of food (snacks rather than normal meals) moderate the container size effect.				x	

Study	Focus	Sample	Method	Results	I	S	D	P	T
Robinson et al. (2014b)	Effect of dishware interventions on energy consumption.	Total: 8 studies, 2006-2013. Setting: real-world: 3, controlled/lab: 5	SR & MA	Meta-analysis results were small, and the authors concluded that dishware size has no consistent effect on food consumption. Various factors may moderate the effectiveness of dishware interventions.				x	
Wadhera & Capaldi-Phillips (2014)	Effect of visual cues (e.g., visibility, color, portion size, shape, number) on food consumption.	Total: 111 studies, 1952-2013.	SR	Changing the microstructure of eating does affect energy intake. Changing the appearance of food can alter perceived flavor, reduce intake of unhealthy food, and help to overcome food neophobia of healthy foods.				x	
Zlatevska et al. (2014)	Effect of portion size on consumption.	Total: 52 studies, 1994-2013. Varying sample sizes between different analyses.	SR & MA	Increasing portion size does increase consumption (Cohen's d=0.45). On average doubling portion size increases consumption by 35%.				x	
Reviews of multiple types of interventions									
Allan et al. (2017)	Choice architecture and financial interventions at the workplace.	Total: 22 studies, 1976-2014.	SR	Thirteen out of 22 studies reported healthier choices (effect size small to medium). Overall design and reporting of studies was poor which precluded a MA. Multicomponent interventions often impair identification of single mechanisms.	x	x		x	x[a]
Arno & Thomas (2016)	Effect of nudges on adult dietary behavior.	Total: 37 studies, 2004-2014. Setting: real-world: 20, controlled/lab: 17.	SR & MA	Nudges are an encouraging strategy to promote healthier eating choices among adults. On average, nudges provide a 15.3% increase in healthier consumption choices.	x	x		x	
Broers et al. (2017)	Nudging interventions to increase F&V choices.	Total: 20 studies for the review, 12 for the meta-analysis, 2000-2015.	SR & MA	Medium but significant effect on choice of F&V (Cohen's d = 0.3). Altering placement had stronger effects than altering properties of the food.		x		x	
Deliens et al. (2016)	Interventions to improve diets among university students.	Subset: 6 studies, 2001-2014.	SR	Overall positive summary of point-of-purchase interventions (i.e. health prompts, increased availability) with some increasing F&V consumption and others reducing junk food.		x		x	
Escaron et al. (2013)	Interventions in supermarkets and grocery stores to foster healthier food choices.	Total: 58 studies, 1978-2012.	SR	Evidence was insufficient for sole point-of purchase interventions (e.g. labels, highlighting healthy choices etc.). Multilevel interventions also including price, availability, and promotions hold promise, but evidence for effectiveness remains limited.		x		x	x[a]

Study	Focus	Sample	Method	Results	I	S	D	P	T
Grech & Allman-Farinelli (2015)	Interventions in vending machines to improve diet and weight status.	Total: 12 studies, 1993-2014.	SR	While effects of point-of-purchase nutritional information seems limited, health claims and colored labels suggest more positive results. Strong evidence that increasing availability and/or reducing the price of healthier options fosters choice. No evidence on overall diets and weight.	x	x		x	x[a]
Hendren & Logomarsino (2017)	Effect of worksite cafeteria interventions on fruit and vegetable consumption.	Total: 18 studies, 1980-2016.	SR	The authors find price incentives, marketing material (e.g., nutritional labelling, posters), and menu modification (e.g., portion size, increased variety and improved placement) to effectively increase fruit and vegetable consumption. Insufficient data precluded a MA and assessment of specific interventions.	x	x		x	x[a]
Hillier-Brown et al. (2017)	Impact of public-health interventions on sales of ready-to-eat meals.	Total: 30 studies, 1997-2015.	SR	The authors assess the overall impact of the interventions as negligible and inconsistent. Choice restriction and incentives seem effective, while less intrusive interventions (i.e., labels, calorie information) show mixed or no effects.	x	x	x		x[a]
Kahn-Marshall & Gallant (2012)	Effect of environmental and policy changes on health behaviour (i.e., diets & physical activity).	Total: 27 studies, 1995-2010; 8 focus exclusively on dietary choices.	SR	Inconclusive evidence for the overall effectiveness of health behaviour interventions. Multicomponent and dietary interventions (vs. physical activity) seemed more effective, but provided only modest improvements in diet.	x	x			
Kaur et al. (2017)	Impact of health-related claims on dietary choices.	Total: 31 studies, 2003-2016, of which 17 studies are included in the MA.	SR & MA	Based on the MA, health and nutritional claims increase choice in experiments by 75%. Effects might be smaller in real-life settings, and caution with regard to publication bias is warranted.	x	x			
Lycett et al. (2017)	Nudges to improve dietary behaviour of children at home.	Total: 40 studies, 2003- 2015.	SR	83% of the studies showed a positive effect, with stronger findings for older children. This included changes in presentation, availability, sizing, prompting and priming, as well as mixed interventions.		x		x	
Nørnberg et al. (2015)	Choice architecture interventions to increase vegetable intake and behavioural change in schools.	Total: 12 studies before December 2013	SR	Overall, inconclusive results of nudges to foster vegetable consumption. Lack of evidence and heterogeneity contribute to this finding. Future research should study attitudes as well.		x		x	x[a]

Study	Focus	Sample	Method	Results	I	S	D	P	T
Osei-Assibey et al. (2012)	The influence of environmental factors on overweight and obesity among children.	Total: 35 studies, 1978-2011.	SR	Results suggest that reducing exposure to promotions for calorie-dense foods, smaller portion sizes, and providing alternatives to sugar-sweetened beverages are likely to affect dietary choice in children aged 8 and younger.		x		x	
Roy et al. (2015)	Food-environment interventions to improve dietary behaviour in universities.	Total: 15 studies, 1998-2014.	SR	Several single interventions show promise, such as food labelling, increased availability of healthy products, and smaller portion size of unhealthy items. Due to the heterogeneity of the studies, no overall assessment is possible.	x	x		x	x[a]
Shemilt et al. (2017)	Effect of health claims (e.g., low fat) on selection and consumption.	Total: 26 studies, 1994-2014.	SR & MA	Exposure to low-fat labels and equivalent can change perception rather than consumption, which might lead to self-licensing effects. Overall evidence is of very low quality.	x	x			
Skov et al. (2013)	Choice architecture to change eating in the self-service setting.	Total: 12 studies, 1984-2012.	SR	Overall evidence is inconclusive. Results from container and cutlery size and payment method interventions are inconsistent. Some evidence for health messages and labelling at point-of-purchase.	x	x		x	
Wilson et al. (2016)	Effectiveness of nudging interventions on healthier choices.	Total: 13 studies, 2010-2014.	SR	Evidence remains inconclusive, and only some studies show that nudging can be effective for influencing healthier food and beverage choices. Further testing of nudging is needed across various populations and contexts to determine the most effective intervention.	x	x		x	

[a] including free offering or price discounts of healthy food, which does not constitute a behavioural intervention or nudge in the classical sense.

Notes: Number of individual experiments might differ from number of studies in some reviews. GDA = Guideline Daily Amount, MA = Meta-analysis, RCT = Randomized controlled trial, SR = Systematic review, MTL= Multiple traffic light. I = Provision of information, S = Use of salience and social norms, D = Changes in the default, P = Changes to the physical environment, T = Incentives and pre-planning.

Table A1: Search terms

TITLE (("nudg*" OR "intervention" OR "choice architecture" OR "environment*" OR "label*" OR "information" OR "fact" OR "claim" OR “prim*” OR “prompt” OR “reminder” OR “default” OR “salience” OR “message” OR "plate*" OR "portion*" OR "packag*" OR "container*" OR "place*" OR "incentive" OR "*planning" OR “*commitment*”) AND ("review" OR "meta analysis")) AND TITLE-ABS-KEY (("food" OR "diet*" OR "vegetables" OR "fruit" OR "eat*" OR "calori*" OR "meal" OR "menu" OR "energy" OR "nutrition*") AND ("selection" OR "choice" OR "behaviour" OR "chang*" OR "consum*")) AND (LIMIT-TO (PUBYEAR , 2010 - 2017)