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Changing diets - Testing the impact of knowledge and information nudges on sustainable dietary choices

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ABSTRACT

A shift to more sustainable diets is needed to ensure food security and to reduce the pressure on the environment. Yet, many consumers have misconceptions about the environmental impacts of their diets and lack knowledge on how to prepare sustainable meals. This study uses a mixed-methods approach to develop four information nudges and to test their impact on dietary choices among a representative sample of Dutch consumers. A 2 × 2 between-subjects design crossing type of information (procedural versus declarative) with type of impacts (health versus environmental) is applied. The environmental impact is measured in terms of CO_2 emissions, land use and water use. We find that pre-intervention knowledge about sustainable or healthy diets is related to the sustainability of participants' dietary choices. Procedural knowledge on how to prepare a healthier meal has the greatest potential to influence dietary behavior, in particular for participants without prior self-reported dietary restrictions.

1. Introduction

In the coming decades, society will have to provide food security for the growing global population, while at the same time shifting to healthier diets (WHO, 2004, pp. 1–385) and decreasing human impact on the climate, freshwater and biodiversity (Bruinsma, 2017; Hoekstra & Mekonnen, 2012; Smith et al., 2008). However, global trends show an increase of consumption of meat, eggs and dairy, which implies that land use is dominated by livestock production (Alexander et al., 2015). The challenge of combining food security with decreasing human impact on the planet may be approached with demand side strategies which target dietary change and the reduction of food waste (Alexander et al., 2017; De Laurentiis et al., 2018). Yet, measures to promote sustainable food consumption need to be designed in the light of persistent consumer misconceptions regarding sustainable food choices (Camilleri et al., 2019; Lazzarini et al, 2017, 2018). For instance, many consumers overestimate the importance of distance to production country in determining the sustainability of a product, whereas mode of transport and seasonality are largely underestimated (Lazzarini et al., 2018; Tobler et al., 2011). At the same time, food misconceptions are not limited to the definition of sustainability, but are also observed in varying interpretations of what is a 'balanced diet' (Dickson-Spillmann & Siegrist, 2011).

The general consensus is that a sustainable diet largely corresponds to a nutritionally healthy diet (Clark et al., 2019; MacDiarmid, 2013; Ruini et al., 2015). In fact, the Food and Agriculture Organization of the United Nations (FAO) defines sustainable diets as 'those diets with low environmental impacts, which contribute to food and nutrition security and to healthy life for present and future generations' (FAO, 2010, p. 7). Such a healthy, environmentally friendly diet is characterized by a large intake of vegetables and fruit, while protein intake is minimized and mainly plant-based (Donati et al., 2016).

Even though recent studies show that consumers in the US (Ballew et al., 2019) and Europe (Fischer et al., 2019; Shi et al., 2016; Tobler et al., 2012) are rather knowledgeable about climate change, they remain mostly uninformed on the broader environmental impacts of their diets (Camilleri et al., 2019; Lazzarini et al., 2017). The multifaceted nature of sustainable food choices, and contradicting information on the footprint, makes it hard for consumers to learn about and act upon the information available (Grunert, 2011). Environmental impact is diverse concept and is often quantified by using three indicators: carbon footprint (CO_2 equivalent emissions), ecological footprint (land

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needed to regenerate resources) and water footprint (water needed to regenerate resources). For both the provision of sustainability and nutrition information it is still unclear how to present it to consumers — in general or on front-of-package labels — and to what extent consumers are able to process such information and translate it into behavioral change (Bernard et al., 2019; (Campbell-Arvai et al., 2014); Ikonen et al., 2020; Sanjari et al., 2017).

Our work is closely related to the work of Röös et al. (2014), who developed a traffic light meat guide to facilitate better choices by interested consumers, to make environmental information understandable to the public. Their guide summarizes the environmental impacts of several types of meat on carbon footprint, biodiversity, chemical pesticides and animal welfare. The meat guide was recently evaluated by five focus groups and was found to be suitable for the audience and stimulating understanding of the trade-offs of chosen food products (Spendrup et al., 2019). Nevertheless, to our knowledge the behavioral effects of the Swedish meat guide have not yet been studied. Kaljonen et al. (2020) on the other hand, have examined the behavioral effects of a single climate label and several nudges to promote sustainable eating in a workplace lunch restaurant. The authors draw attention to a series of practical challenges and tensions for menu planning and recipe development.

Here, we explore various ways to present health and environmental footprint information to consumers with the aim to stimulate dietary change. This study is one of the first to assess the impact of such information on actual dietary choices, by examining a representative sample of Dutch consumers across two survey waves. The environmental impacts of self-reported meals are measured in a precise way, based on Life Cycle Assessments (LCA), and separately for emissions (kg of CO_2 equivalent emissions), land use (m^2 of land) and water use (L of water). Tobler et al. (2011) show that laymen's understanding of environmental impact differs from LCA impact. Our use of LCA allows for a differentiated understanding of the misconceptions of consumers regarding sustainable dietary choices and how to support them in making more sustainable choices.

1.1. *Improving knowledge for dietary change*

For dietary changes to take place, misconceptions about healthy and sustainable diets should be eliminated by improving knowledge about these diets. In contrast to the association between nutritional knowledge and healthy eating behavior, which has been studied before (Dickson-Spillmann & Siegrist, 2011; Wardle et al., 2000; Worsley, 2002), the relationship between knowledge about sustainable diets and sustainable dietary choices has not been explored in depth. One notable exception is a paper by Vermeir and Verbeke (2006), who used a survey among 456 young adults to assess the link between knowledge, attitude and behavioral intention related to sustainable food choices. They found an association between knowledge and behavioral intention, but they did not explore the link to actual behavior. Vicente-Molina et al. (2013) studied how environmental knowledge affects self-reported pro--environmental behavior in a large scale study among more than 2000 college students across different countries. They find that environmental knowledge is positively related to pro-environmental behavior, measured as recycling, public transport use and green purchasing. Finally, Torabian-Riasati et al. (2017) examined the relationship between food-sustainability knowledge and self-reported dietary choices among 230 U.S. College students and observed a strong relationship between knowledge and behavior. As to our knowledge, the current study is the first to test the relationship between knowledge about sustainable diets and actual sustainable dietary choices in a large and representative sample of consumers.

Following Wardle et al. (2000); Dickson-Spillmann and Siegrist (2011); Torabian-Riasati et al. (2017), who found a strong correlation between nutritional knowledge and healthy eating behavior, we expect to find a similar relationship between knowledge about sustainable diets and actual sustainable meal choices.

Hypothesis 1a. Pre-intervention knowledge about sustainable diets is positively correlated with sustainable dietary choices.

Given that the environmental impact of an nutritionally healthy diet largely corresponds to the environmental impact of a sustainable diet (Clark et al., 2019; MacDiarmid, 2013; Ruini et al., 2015), it should be possible to improve sustainable dietary choices by stimulating healthy dietary choices. Following the rationale of the first Hypothesis, we expect that respondents who make food choices based on knowledge about healthy diets generally make more healthy dietary choices, which means to more sustainable dietary choices as well. Interestingly, Lazzarini et al. (2016) found in a sample of 85 Swiss consumers that consumers also perceive the correlation between environmental friendliness and healthiness of food products to be high.

Hypothesis 1b. Pre-intervention knowledge about healthy diets is positively correlated with sustainable dietary choices.

The studies by Lazzarini et al. (2017), Lazzarini et al. (2018) and Camilleri et al. (2019) showed that many consumers do not have a good understanding of the environmental footprint of their chosen diet. Especially the use of heuristics such as selecting food products based on country of origin can mislead consumers (Lazzarini et al., 2017). Camilleri et al. (2019) find that individuals tend to underestimate food-related GHG emissions. Regarding the wider environmental impact of various food items, Lazzarini et al. (2018) find that consumers' misconceptions are particularly strong for protein sources. These misconceptions make it difficult if not impossible for consumers to make more sustainable choices. We expect to confirm those findings in that individuals rate the overall sustainability of meals inaccurately.

Hypothesis 1c. The perceived overall sustainability of meals is uncorrelated with the objective environmental impacts of meals.

Another relevant question is what type of information is suited to improve sustainable dietary choices of consumers (Grunert, 2011). Ideally, information creates knowledge, which overcomes misconceptions, and positively influences individual decision-making. Yet, an overload of information is likely to result in higher cognitive load, and suboptimal choices (Gourville & Soman, 2005), especially when consumers take decisions under time pressure (Sanjari et al., 2017). Hence, to change behavior via improving knowledge, one needs to balance the type and volume of information. Ratner et al. (2008) argues that information about an end goal should be put into perspective of an individual's current behavior to be fully effective. White et al. (2019) suggests that information and knowledge are necessary but not sufficient conditions for taking environmental actions. To induce behavioral change in consumers, information needs to 'capture the attention, overcome skepticism and improve their involvement' (Stern, 1999, p. 467).

Product labels could be a source of information when the choice for dietary chance is made, in the supermarket. A contextual cue is especially beneficial in habitual behavior, such as food choices White et al. (2019). However, product labels about various dimensions of environmental sustainability of food, including carbon footprint, ecological footprint and water footprint, can quickly become complex and difficult to process. Previous research has shown that the understanding of sustainability labeling schemes is generally limited (Hoogland et al., 2007; Janssen & Hamm, 2012; Nilsson et al., 2004). Grunert et al. (2014) showed that many consumers do not correctly interpret the sustainability labels on food products. While findings of Camilleri et al. (2019), Vanclay et al. (2011) and Brunner et al. (2018) suggest simple footprint indicators have the potential to shift consumption towards more sustainable food choices, often the effect of providing label information on dietary change is weak or non-existent (Ikonen et al., 2020). A recent review by Vandenbroele et al. (2020) showed that the effects of descriptive labelling on sustainable food choices are mixed and quite sensitive to personal traits such as environmental concern. The authors

also call for future research to determine whether evaluative labelling (such as traffic light color coding) may lead to compensatory consumption.

Besides front-of-package labels, information nudges (Coffman et al., 2015; Jones et al., 2015; Miesler et al., 2017) are a possible way to induce behavioral change. Information nudges are a way of 'structuring the information environment in subtly different ways that can easily and even unconsciously influence people's choices and behaviors in desired directions' (Todd et al., 2011, p. 23). They aim to provide information in an appealing way, both visually and verbally, and to educate people while activating certain heuristics and behavioral biases (Johnson et al., 2012; Jones et al., 2015; Miesler et al., 2017). Using a reduced number of alternatives, an increased focus to changing one specific type of behavior, and a partitioning of suggested changes have been proven to be the most effective ways to design information nudges (Johnson et al., 2012). Miesler et al. (2017) test several information nudges to stimulate the uptake of disability insurance among young people and find that the nudges are successful in raising awareness of the risk of future disability, although they do not stimulate the search for more information about insurance options. However, Jones et al. (2015) report that disclosing information such as payment due date and late fees, payoff times and penalty interest rates on credit card bills positively impacts consumers' payment behaviors. Information nudges have been applied successfully to reduce consumer food waste (Hebrok & Boks, 2017; Reynolds et al., 2019; van der Werf et al., 2021). We therefore aim to test whether treating consumers with an information nudge disclosing the impacts of their food choices stimulates more sustainable dietary choices.

Hypothesis 2. Providing an information nudge increases sustainable dietary choices.

One alternative to simple disclosure of the impacts of food choices is to provide consumers with decision-making rules for creating meals with a low environmental impact. Simple rules that integrate a limited amount of information can help consumers to decide between different lunch options Schulte-Mecklenbeck et al. (2013). Kause et al. (2019) explored how consumers generate such rules, and how they perceive the effectiveness of commonly used rules such as 'buy local' and 'buy seasonal'. They found that respondents use ambiguous rules and are unable to identify the most effective ones. Therefore, consumers could benefit from simple and effective rules such as 'buy white instead of red meat', putting emphasis on health and environmental benefits of following certain rules, rules across food groups, and relative comparisons in percentage format (Kause et al., 2019). Providing consumers with simple rules rather than complex information aligns with the distinction between declarative knowledge and procedural knowledge, i.e. 'between knowing that and knowing *how*', which involves different cognitive processes (ten Berge & van Hezewijk, 1999, p. 605). In the context of food choices, procedural knowledge is 'knowledge about how to do things', such as choosing wine for a meal or selecting a low-salt packet of soup (Worsley, 2002, p. S579). We expect that procedural knowledge will be easier to process for respondents, which could lead to a stronger behavioral change than declarative knowledge.

Hypothesis 3. An information nudge providing procedural knowledge leads to a stronger change in sustainable dietary behavior than an information nudge providing declarative knowledge.

1.2. Enhancing motivations for dietary change

Another open question is whether consumers are more inclined to switching to a more sustainable diet if the dietary change is communicated as beneficial for their health or as beneficial for the environment. O'Riordan and Stoll-Kleemann (2015), for example, emphasize that the strongest motivations for reducing consumption of animal products are animal welfare and personal health, whereas environmental protection usually ranks lower on the list of motivations. Likewise, Mullee et al. (2017) explored motivations for different diets in a large population survey in Belgium and found that health is the most frequently named reason for switching to a more plant-based diet. We therefore expect that health-related information has a stronger effect than sustainability information (Mullee et al., 2017; O'Riordan & Stoll-Kleemann, 2015).

Hypothesis 4. An information nudge about healthy diets leads to a stronger change in sustainable dietary behavior than an information nudge about sustainable diets.

In sum, the present research aimed to determine the relationship between knowledge of healthy and sustainable diets, motivations, different information nudges and actual dietary choices. After sharing insights from a scoping study including surveys and interviews, we present results of an intervention study. We test whether pre-intervention knowledge of healthy and sustainable diets as well as two types of information (declarative versus procedural) about two different types of impacts (health versus environmental) of specific meal ingredients can increase the sustainability of actual dietary patterns. Building on the results of the scoping study, we developed an intuitive method to survey respondents' dietary patterns, by letting them report the ingredients of recently consumed main meals. The precise environmental impact of these meals was determined by Life Cycle Assessment (LCA) methods, which allowed for a careful and repeated measurement of actual sustainable consumption choices over time.

2. Methodology

Our sequential mixed-methods approach consists of a scoping study to identify common misconceptions and motivations with regard to sustainable food consumption and an intervention study to test the influence of different information nudges on the environmental impacts of actual dietary patterns. The scoping study was carried out among students and employees of a Dutch university. It included two surveys and a qualitative interview to identify the most common motivations and misconceptions with regards to sustainable food consumption. A first survey explored the motivations of students and employees to shift towards a more sustainable diet by combining several scales. We asked them to participate in a second survey in they provided supermarket receipts for five recently consumed meals. Additionally, we asked questions about animal welfare. Finally, interviews with a subset of these respondents revealed some of the reasoning behind food consumption. The results of the scoping study led us to develop an intervention in the form of an information nudge, which was administered in an online survey.

2.1. Procedure of the scoping study

The scoping study targeted millennials from Western European countries to minimize variability in food habits. Students and employees were recruited from a university in Amsterdam, The Netherlands, through an invitation on the internal message board (VU-net).[3] No reference was made to the research goal. This invitation included a link to a sign-up survey, which included a question on year of birth and country of origin. Respondents born between 1980 and 2000 and from one of the following countries: Belgium, Netherlands, Luxembourg, Sweden, Norway, Denmark, Finland, United Kingdom, Ireland, France, Germany, Austria and Switzerland, were added to the recruitment pool. Survey invites were sent to the recruitment pool participants. This approach was pre-registered.[4]

The first survey included modules on price consciousness (five items;

[3] Invitation text: *We want you to participate in an ongoing research project of VU researchers! We are an interdisciplinary team of researchers would like to know what kind of food products you consume and why.*

[4] https://aspredicted.org/fi6h4.pdf.

Lichtenstein et al., 1993), environmental concern (three subscales of four items each, measuring biospheric concern, altruistic concern and egoistic concern; Schultz, 2001), health motivations (six items; Michaelidou & Hassan, 2008), subjective social status (Adler et al., 2000), green consumption values (the GREEN scale, six items; Haws et al., 2014), food involvement (three items, different versions by gender; de Boer et al., 2007), hedonism values (three items, different versions by gender; Sandy et al., 2017). In addition, the survey included several background variables: gender, household, student, faculty, educational level of parents, religion, diet, meat eating days (times per week), and preparing dinner days (times per week).

In the second survey, participants were asked to share receipts from grocery shopping for five recently home-cooked meals. Pictures or screen captures of receipts could be uploaded into the survey software. An example picture showed how to cover (or strike-through) the products that were not used as ingredients in the meal (e.g. toiletries). For each meal, we asked respondents to report a date, the number of guests, dietary restrictions, the main protein source, the bar-codes of the ingredients[5] and the person who paid for the meal. The second survey further included several background variables (pet ownership; rural versus urban environment; belief in anthropogenic climate change; self-reported environmental footprint; self-reported sustainable food consumption; self-reported hedonism) and several scales to measure environmental skepticism (nine items; Goh & Balaji, 2016), animal welfare concerns (seven items; Cembalo et al., 2016), product quality consciousness (three items; Völckner, 2008) and environmental knowledge (seven items; Paço & Lavrador, 2017).

We applied theoretical sampling based on diet, knowledge and attitudes reported in the first survey to select a diverse sample of interviewees from the completes of the second survey. During the interviews we focused on beliefs, knowledge, and social influence, and asked specific questions about the motivations for a diet, how to create a sustainable meal, how to rank products according to their environmental impact, and how the social surroundings influenced dietary choices. The interview guidelines can be found in Appendix A - Interview guidelines. In total, 23 1-h interviews were conducted, aimed at identifying prevailing misconceptions on sustainable and healthy diets. Respondents were remunerated with vouchers ranging from 5 euro (for the first survey) to 35 euro (two surveys and the interview).

2.1.1. Results of the scoping studies

Green consumption values,[6] health motivations, and altruistic and biospheric concerns differed significantly across self-reported diets among the 317 respondents who finished the first survey. On average, on a 5-point scale ranging from disagree to agree, people reported high environmental concern (altruistic values: $mean = 4.27$, $sd = 0.69$) and low health motivations ($mean = 3.97$, $sd = 0.79$), price motivations ($mean = 2.67$, $sd = 0.62$) and environmental consumption values ($mean = 3.66$, $sd = 0.81$). Vegetarian and vegan participants scored higher on green consumption ($F = 22.97, df_1 = 3, df_2 = 308, p = .000$, $\eta^2 = .18$), altruistic ($F = 3.266$, $df_1 = 3$, $df_2 = 310$, $p = .022$, $\eta^2 = .04$) and biospheric concern ($F = 6.51$, $df_1 = 3$, $df_2 = 310$, $p = .000$, $\eta^2 = .06$) than respondents not indicating to follow a specific diet, whereas people with dietary restrictions for health reasons were more likely to be motivated by health ($F = 7.951$, $df_1 = 3$, $df_2 = 309$, $p = .000$, $\eta^2 = .07$). The results further showed that health motivations and biospheric concerns have a positive correlation with green consumption values, contrary to hedonism, which has a negative correlation. These effects remained significant after controlling for the type of diet respondents followed. Compared to those without dietary restrictions, people who eat meat sporadically or not at all were more likely to report that they intend to consume environmentally friendly. In the following, we will focus on how sustainability and health play a role in dietary choices.

Both the quantity (attrition) and the quality of the data retrieved through the receipt upload were low. Uploading receipts of five different meals turned out to be quite a burden to participants and even completed responses proved quite challenging to analyze, as the bar codes could not always be tracked to online product descriptions. The completely documented meals, however, showed that dietary choices were not always in line with intentions, even for the respondents who expressed a strong willingness to consume environmentally friendly. Since only 63 respondents finished the second survey, and are very unlikely to be representative of our student sample, we do not report the answers to the multi-item scales in this survey.

The subsequent interviews revealed a large variety of motivations for dietary choices. Following Gioia et al. (2013), the principal researcher and a student-assistant coded the interviews line-by-line which resulted in a list of emerging concepts (see Appendix B - Emerging theoretical concepts) that included three main themes: motivations, knowledge, and social influence. We compared interviewees with respect to their reported diet in the first survey. As for motivations, vegetarians and vegans talked most about health, environment, country of origin, and taste. More than the other respondents, flexitarians mentioned packaging, pesticides and waste but were least likely to mention seasonality. People with dietary restrictions mentioned the climate and certification to be related to their food choices while people without such dietary restrictions did not mention climate at all. The two participants with dietary restrictions for health reasons were indifferent about environmental issues and mainly cared about their appearance or weight.

Many struggled with how to value these different aspects of food sustainability. People demonstrated declarative knowledge by addressing production processes, country of origin, pollution, and the use of pesticides. However, most often they focused on two aspects throughout the interview. Integrating various aspects of sustainable food choices was considered difficult and many trade-offs were discussed: *"I think it is really difficult because even people that are really interested by that, sometimes they contradict each other. So I think I would take a lot of information that I have and do a mix by myself and say okay, this is what I take and what I do"* [R17, No diet] Others explicitly stated that they do not know enough about sustainable food choices: *"Um. I actually don't know, think it's a wild guess. I looked at where it was from … rice needs a lot of water to grow. I think it's less important for potatoes. The working conditions to grow rice are not always very optimal."* [R1, Flexitarian]. Sometimes the uncertainty was related to specific aspects, such as water use: *"I would be confident in my choice, but I would also be open for improvements, because I don't feel like I'm that knowledgeable on sustainability. Because I don't necessarily know how much water and pesticides [are] involved in every product."* [R3, Flexitarian] Regularly, people would emphasize that they lacked knowledge to make a sustainable choice: *"I wouldn't really know how much water is needed inside the Netherlands and outside the Netherlands, for example. So I couldn't really make a well-informed decision about that."* [R18, Vegetarian].

Only three people integrated all topics in their answers, and all three adhered to a diet (flexitarian, vegetarian or vegan). Although they also expressed uncertainty, these interviewees balanced different arguments to formulate their answer: *"Well, that's why I know that, like, meat and beef per se is, like, not so good. Well, it's not actually CO_2, but it's a lot of methane that cows produce. So that's bad. Umm, so that's also I guess for the cheese a bit. And everything that has to be flown in, that's also producing a lot of CO_2. But from the whole growing process, and uh, like the pr-mmm, when they process it, I'm not that aware"* [R22, Vegan] To solve this uncertainty, people used rules of thumb to answer the questions, where organic production, seasonality, packaging, and animal welfare were

[5] Respondents were instructed as follows: *Download the app 'Barcode Scanner' or a similar app on your smartphone. This app allows you to scan each product using your smartphone, go to history, and save the list of bar-codes to your drive or email address. Please paste the bar-codes of the ingredients of this meal here.*

[6] *The tendency to express the value of environmental protection through one's purchases and consumption behaviors*(Haws et al., 2014, p. 336).

most often mentioned. To assess the sustainability of a product, people discussed whether: a) the product came from far away, b) the product was organic, and c) the product was meat-based. *"It has to be far away, and not the seasonality. So, I thi- Oh, and meat. Meat is a lot of environmental damage."* [R12, No diet] *"I know that transportation is a really-has a really big impact, so I'll say the chicken filet."* [R21, Vegetarian].

Despite these rules of thumb, most respondents got confused when asked to rank several fruits and vegetables, carbohydrates and protein products from environmentally friendly to environmentally unfriendly (see Figure A1 for an overview of products discussed during the interviews). When asked how they usually get their information about sustainable food choices, most respondents were confident that they could trust most media sources, such as documentaries, online sources and newspapers. A small minority sought information in research reports issued by government organizations. Strikingly, while some mentioned to avoid meat to reduce their impact, most interviewees admitted not to know how to prepare a sustainable meal.

2.1.2. Directions for intervention study

The scoping study showed that motivations differ between people with and without dietary restrictions. In the first survey we observed that many people considered themselves flexitarian, even though they did acknowledge to eat meat many times a week which pointed to misconceptions about what is a restricted diet. The receipt study in the second survey was less useful as only a few people submitted (incomplete) receipts. When asked about motivations for sustainable food choices during the interviews, people with dietary restrictions often mentioned conservation of the environment while people without such restrictions often mentioned health benefits. This distinction between health and sustainability as a motivation for specific food choices is supported by the first survey and further explored in the intervention study. Another takeaway from the interviews is the lack of knowledge: Even if people are willing to maintain a sustainable diet, making actual choices in line with low environmental impacts was not experienced as an easy task. Furthermore, many interviewees struggled to assess the environmental impact of products, mentioned that they feel unsure about how to prepare a sustainable meal and argued that if provided with instructions, they would make them feel more confident. Given that the scoping study included a sample of students who are likely to be more knowledgeable, we expect these knowledge issues to be more substantial among the general population.

2.2. Intervention study

Based on the results of the scoping study, we carefully developed four different information nudges to stimulate more sustainable dietary choices. The effect of these interventions was tested in a two-wave online survey on a representative sample of the Dutch adult population ($n = 1264$), recruited by Panelinzicht in May 2020, and administered using Qualtrics survey software. Sample size analysis for a single coefficient in multiple regression in G*Power (Faul et al., 2007) indicated a minimum sample of 126 per group to find a small-medium effect size ($f_2 = 0.05$) at 5% α-error probability and 80% power. Based on the budget and an expected follow-up participation rate of 55%, we aimed for 650 complete responses in the second survey, which allowed for five conditions with a sample size of 130 each in the second survey. At the start of the first survey, each participant was randomly assigned to one of five conditions: control (no intervention, $n_{survey1} = 251$, $n_{survey2} = 151$), declarative environment ($n_1 = 247, n_2 = 140$), declarative health ($n_1 = 251, n_2 = 145$), procedural environment ($n_1 = 255, n_2 = 149$) or procedural health ($n = 251$, $n_2 = 148$). The control group did not receive any information nudge. The information nudges provided either information on health or environmental impacts of certain meal ingredients, and were presented in the form of declarative knowledge (general impact of ingredients of a specific meal) or procedural knowledge (instructions on how to prepare such a meal). In both waves, participants were asked to report the ingredients of three recent main meals using an extensive drop-down list. In the scoping study, respondents were asked to upload receipts and bar codes of the ingredients of five recently consumed home-cooked meals. Both the quantity and the quality of the data retrieved through the receipt uploads were low, which is why we developed this more user-friendly and intuitive procedure. Participants first answered questions about the ingredients of three home-cooked meals consumed in the last week and several control variables. Towards the end, the information nudge was shown to the participants in the treatment groups. Seven days after completing the first survey, respondents were asked again to report three meals they consumed in the preceding week, allowing us to observe any changes in dietary patterns between the two waves. All hypotheses were formally preregistered prior to data collection[7] and the university's ethics committee approved the study in March 2020. The intervention study was pretested on a sample of 208 students, excluding all students who had participated in the scoping study.

2.2.1. Survey questions

After questions about demographics (age, gender, living situation and country of socialization[8] and dietary restrictions, we measured pre-intervention knowledge. To measure knowledge about healthy food consumption, six questions were selected from the scale of Dickson-Spillmann and Siegrist (2011) which were unambiguous but not obvious to answer. Using help from an expert from the field, we carefully translated the questions to Dutch, and rephrased them so that three questions were *true* and three were *false*. Following the original scale, correct *true* answers and correct *false* answers were scored as 3, *don't know* answers were scored as 2 and incorrect answers were scored as 1. We computed the sum of the 6 items for each respondent. We constructed a similar scale for the environment treatment on sustainable food consumption knowledge.[9] The complete survey can be found in Appendix C - Survey questions.

2.2.2. Observed dietary patterns

To enter the main ingredients of the three meals they had consumed in the past week, respondents could use a drop-down menu allowing respondents to type, auto-complete and select each ingredient from a list of 278 ingredients. The ingredient list was constructed based on the ingredients of the scoping study and several pretests. On the next page, respondents were asked to indicate for each meal who was responsible for preparing it, how sustainable they considered this meal and on which day of the week they had consumed it.

2.2.3. Intervention

For the intervention, the information nudges, we used a 2 × 2 between-subject design, varying the type of information (declarative versus procedural) and the type of impacts (environment versus health). In the declarative information treatments, we informed participants about the consequences of replacing certain ingredients in a meal on health/environmental impacts. The suggested replacement of ingredients was tailored to self-reported diet (i.e. vegetarians would not be informed about meat replacements). Information was presented using bullet points and accompanied by a simple visualization, based on a recent review of the implications of various ingredients on both environment and health (Clark et al., 2019). To enhance the credibility of the

[7] https://aspredicted.org/qh4t3.pdf.

[8] *In which country have you lived (longest) until the age of 12?*.

[9] Note that we measured general knowledge only in Survey 1. Correct answers were provided in Survey 2.

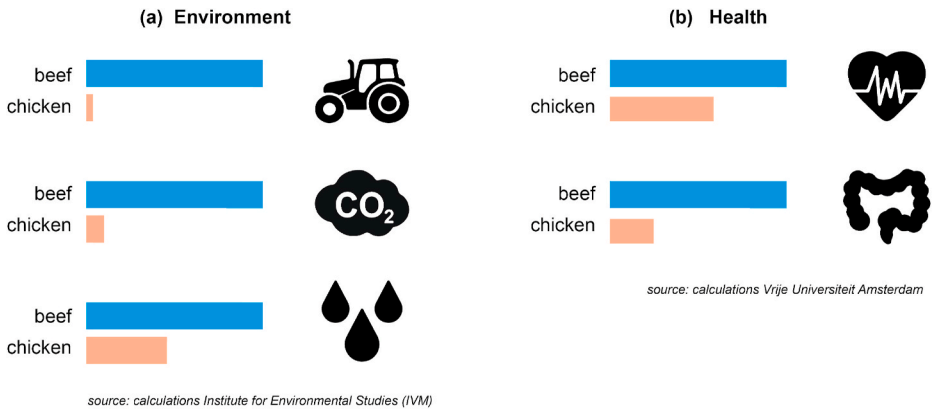

Fig. 1. Declarative environment intervention (A: left panel) and declarative health intervention (B: right panel) for *no restrictions* diet.

message, the information source was displayed in a caption. We opted for relative (rather than absolute) comparisons between the alternatives to allow for comparison across treatments. Fig. 1 shows the visualizations presented in the declarative information treatment for a person who indicated to have *no dietary restrictions*, meaning that we could encourage this individual to replace beef by chicken. By motivating respondents to make an incremental change to their current diet, we relate to their prior dietary choices. This personalized information nudge based on self-reported dietary restrictions follows the rationale that an information nudge is most effective when it targets the marginal individual, i.e. the individual that is most likely to change their behavior in response to updating their beliefs (Coffman et al., 2015). It is also in line with the results of Abrahamse et al. (2007) who show that tailored information is more effective than general messages. Finally, personalized messages may be useful to prevent backfiring of informational nudges (Bacon & Krpan, 2018).

In the procedural information treatment, respondents were presented with a bullet list with specific examples of meal replacements. Furthermore, we added a link to a recipe of such a meal at the website of the Netherlands Nutrition Centre.[10] The visual in the procedural information treatment was a picture of the recipe, which linked to the same webpage.

The intervention screen was shown for at least 10 s, forced by the survey software. The software also tracked the time spent on the intervention page, as well as the number of clicks. An overview of the interventions for the declarative information treatment, by type of information (environment versus health) and diet (No restrictions, flexitarian, vegetarian/pescatarian and vegan) can be found in Figure D1 in Appendix D - Screenshots interventions. The overview of interventions for the procedural information treatment can be found in Figure D2 in Appendix D. At the end of the first survey we reported the correct answers of the relevant knowledge questions. Fig. 2 gives an overview the survey for each of the different treatments in the intervention study.

2.2.4. *Calculating the environmental impacts of meals*

In both surveys, respondents described three meals they had consumed in that week. Respondents were asked to report the main ingredients, with a minimum of three, and were reminded that most meals are a combination of carbs, proteins, vegetables and seasoning. To calculate environmental impacts, average weights (or portions) were constructed, using information from the Netherlands Nutrition Centre and major grocery stores in the Netherlands. We then calculated, for each ingredient, emissions (kg of CO_2 equivalent emissions), land use (m^2 of land) and water use (L of water) needed to produce the ingredient, using mean values for each indicator from Life Cycle Assessments (LCA) by Poore and Nemecek (2018). For particular fresh food items (eggplant, avocado, eggs, coconut), the values were updated with values from Clune et al. (2017) and Bais-Moleman et al. (2019) (for emissions) and Mekonnen and Hoekstra (2012) (for water use). The LCA data of all ingredients can be found in a spreadsheet in Multimedia Component 1 (LCA by ingredient.xlsx).[11]

Some respondents were very meticulous and filled in more than five ingredients whereas others sufficed with mentioning only three, which we had defined as the minimum number of ingredients per meal. Simply summing the impacts associated with these ingredients would lead to higher scores for the meticulous respondents, and the conclusion that their meals are less sustainable than those meals for which only the minimum number of ingredients were reported. The following formula was applied to account for this possible bias, normalizing the environmental impacts of a meal by each class of ingredients:

$$impact_{meal} = \sum_{c=1}^{C} \frac{\sum_{g_c=1}^{n_c} impact_{g_c}}{n_c}$$

where n_c is number of ingredients g in class of ingredients c, C represents the four classes (carbs, proteins, vegetables, seasoning), and *impact* may refer to CO_2, land or water use. [12]

3. Results

In total, 1264 responses were completed in the first survey and 737 were completed in the second survey, corresponding to a follow-up

[10] https://www.voedingscentrum.nl/nl/service/english.aspx.

[11] In terms of greenhouse gas emissions, we looked at the reported values of kg of CO_2 equivalent emissions (IPCC 2013 including feedback values). For land use, we used values on m^2 of the terrestrial surface used to produce the item. For water use, we used values on freshwater withdrawals (L of water) to produce the item. The LCA values we used, cover the blue water component of the total water footprint, namely the consumption of surface and groundwater Hoekstra (2017). This way, the impact consumption of green (rainfall) and production of gray water is not considered in the values, meaning that the impact on water resources could have been underestimated.

[12] When calculating the impact per meal, we observed very high correlations between CO_2 and land use (r = .99), even though the values of the product groups as calculated by Poore and Nemecek (2018) relate much lower (r = .79). Other studies have observed lower correlations between land use and GHG (see for example van Dooren et al., 2017). This can be explained by the fact that the product groups are repeatedly used by consumers, having an excessive influence on the impact of the meal. If we would have had more fine-grained data on environmental impact per food item instead of food group, this could be avoided. Unfortunately this is not available. Nevertheless, similarly high correlations between land use and greenhouse gas emissions have been observed in other life cycle assessments, such as Vellinga et al. (2019).

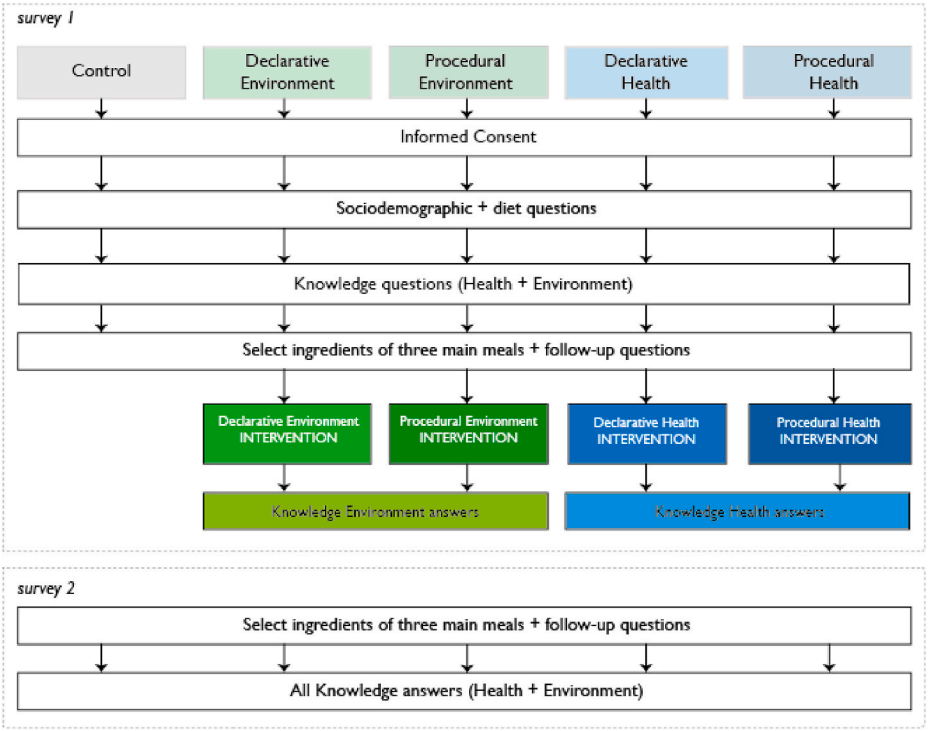

Fig. 2. Design of the intervention study.

Table 1
Descriptive statistics by survey wave.

	Survey 1	Survey 2
Age in years (SD)	50.47 (17.91)	49.61 (17.22)
Gender (%)		
Male	631 (51.2)	371 (50.6)
Female	600 (48.7)	361 (49.2)
Other	2 (0.2)	1 (0.1)
Self-reported diet (%)		
No restrictions	768 (62.3)	449 (61.3)
Dietary restrictions[a]	465 (37.7)	284 (38.7)
Household (%)		
Shared/family	948 (76.9)	567 (77.4)
Single	285 (23.1)	166 (22.6)
Diet-related knowledge (SD)		
Environment	13.76 (1.91)	13.80 (1.89)
Health	14.91 (2.53)	15.00 (2.55)
Observations	1233	733

Notes:[a] Dummy includes flexitarian, vegetarian, vegan and pescatarian diets.

participation rate of 58%. All analysis code can be found in Multimedia Component 2 (Analysis code in R markdown). Table 1 presents the descriptive statistics of respondents, split by survey. The sample was balanced (i.e. no significant differences were found on any of the independent variables across treatment groups or survey waves, using χ^2 tests for the categorical variables and *t*-tests for the continuous variables). The median time to complete the surveys was 11 min for the first survey and 5 min for the second survey. We excluded 31 responses from the analysis for missing answers and nonsense ingredients.[13] The two waves do not differ significantly from the Dutch population in terms of gender, age or education.

We hypothesized that a higher pre-intervention knowledge of either environment (Hypothesis 1a) or health (Hypothesis 1b) aspects of food choices would result in more sustainable meal choices. Table 2 presents an OLS regression of diet-related knowledge on environmental impacts of three meals reported in the first survey, averaged by respondent. Note that the independent variables are not scaled. The negative coefficients for CO_2 and land use show that people with high pre-intervention knowledge levels report meals with significantly lower environmental impacts. In line with our hypotheses, this effect occurs regardless of the type of knowledge (environment versus health). Environmental knowledge seems not to be related to the water intensity of meals. In contrast, health related knowledge is positively associated with water intense meals, which could be explained by the use of many water intense vegetables and fruits. These effects are small but significant which accentuates that increases in knowledge may affect minor changes in actual food choices.

Hypothesis 1c concerned the relationship between the perceived sustainability and the objective sustainability of the reported meals. Note that perceived sustainability of meals (See Appendix C, survey 1, question 15) is not equivalent to pre-intervention knowledge (See Appendix C, survey 1, question 8 and 9). Meals in the first survey corresponded on average to 1.6 kg CO_2 equivalent, 4.6 m^2 of land and 97.8 L of water. Fig. 3 shows that people rated their meals that score higher in CO_2 emissions and land use as slightly less sustainable. The relationship between the perceived and objective impact of the meals is very weak across CO_2 emissions, land and water use. Interestingly, water use seems to be related most strongly to the perceived impact of a meal. This might be caused by meat and dairy products that are often perceived as unsustainable. Overall, people seem to have problems with assessing the sustainability of their meals.

The next hypotheses related to the change in environmental impacts of the meals between the two surveys. In the following analyses, we calculate the change in behavior by subtracting the average environmental impacts of Survey 1 from the average environmental impacts of Survey 2. The treatment effects are separately tested for CO_2, land or

[13] Some respondents reported ingredients that were unlikely to constitute a true meal. To prevent manual judgment of 'true meals', we constructed a function that removed all responses with ingredients starting from the same letter (facilitating quick answering) such as *aioli, allesbinder (cornstarch), amandelen (almonds)*.

Table 2
OLS regression of environmental impact of food choices in Survey 1.

	DV: Average environmental impact of meals in Survey 1					
	CO_2		Land		Water	
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.890***	0.848***	1.003***	0.964***	− 0.751***	− 0.774***
	[0.429, 1.350]	[0.408, 1.287]	[0.543, 1.463]	[0.522, 1.406]	[− 1.212, − 0.290]	[− 1.229, − 0.319]
Diet-related knowledge						
Environment	− 0.034**	− 0.026*	− 0.037**	− 0.029*	0.014	0.019
	[− 0.064, − 0.004]	[− 0.055, 0.003]	[− 0.067, − 0.006]	[− 0.058, 0.00002]	[− 0.016, 0.045]	[− 0.011, 0.049]
Health	− 0.028**	− 0.017	− 0.033***	− 0.023**	0.037***	0.044***
	[− 0.051, − 0.005]	[− 0.039, 0.005]	[− 0.056, − 0.011]	[− 0.045, − 0.001]	[0.014, 0.060]	[0.021, 0.066]
Diet [ref = No restrictions]						
Some diet		− 0.634***		− 0.587***		− 0.371***
		[− 0.744, − 0.524]		[− 0.697, − 0.476]		[− 0.484, − 0.257]
Controls						
Response time > 40 min		− 0.064		− 0.058		− 0.055
		[− 0.304, 0.176]		[− 0.300, 0.183]		[− 0.304, 0.193]
Observations	1233	1233	1233	1233	1233	1233
R^2	0.012	0.106	0.015	0.095	0.011	0.043

Notes:*p<0.1; **p<0.05; ***p<0.01. Dependent variable: Environmental impacts (CO_2 equivalent, land use and water use) of three meals reported in Survey 1, averaged by respondent. Table reports unstandardized regression coefficients with 95% confidence intervals in square brackets. Models 1, 3 and 5 present the main effects of knowledge. Models 2, 4 and 6 control for dietary restrictions and response time.

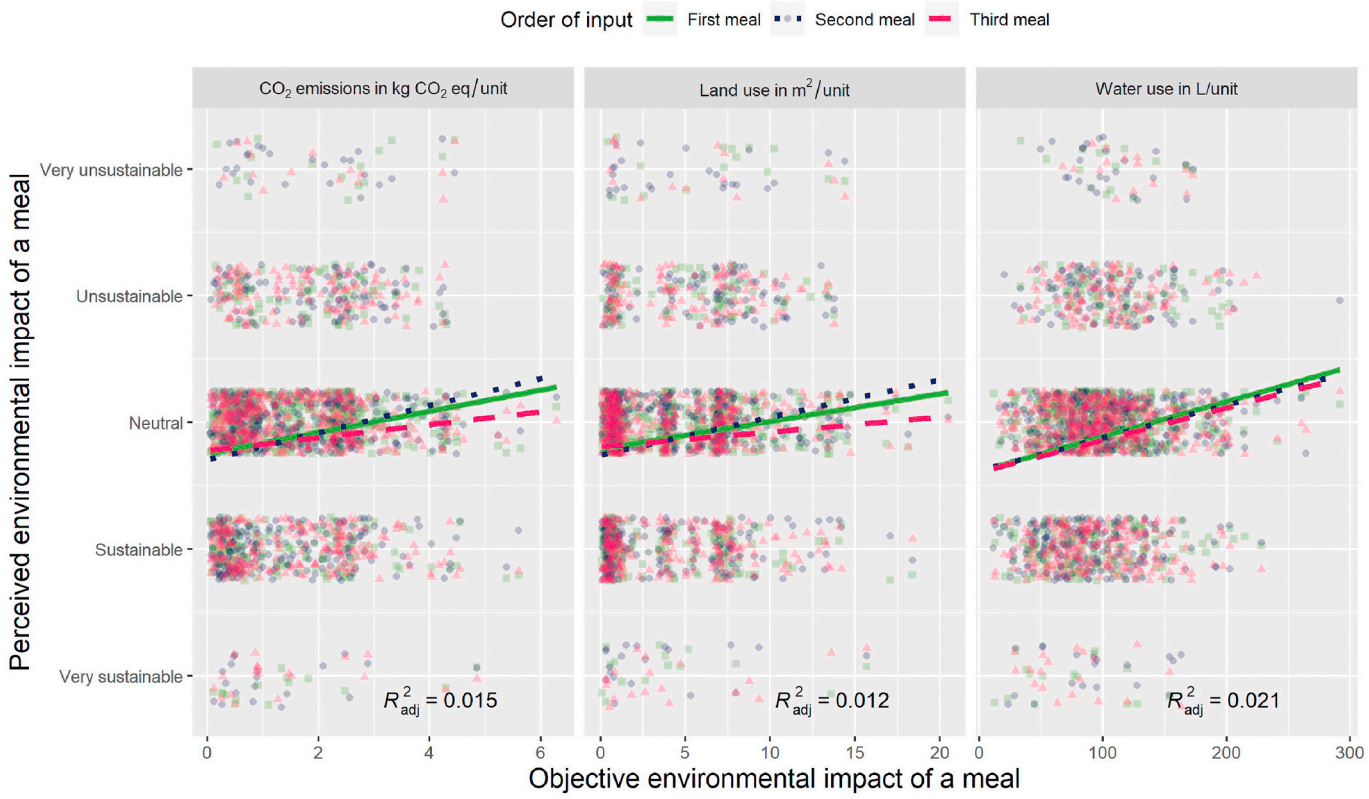

Fig. 3. Objective versus perceived environmental impacts of meals.

water use as they were measured at a different scale. We control for the total time spent on the surveys as this is probably an indication of how precisely people have filled in the ingredients. Again, all (non-dummy) variables are standardized to allow for comparison in terms of strength.

Hypothesis 2 predicted a main treatment effect of our information nudges. Fig. 4 shows the estimated marginal means of an OLS regression of treatment on the change in environmental impacts across the surveys. The model regresses treatment dummies on each environmental indicator, controlling for self-reported diet and response time. It should be noted that negative numbers indicate a change towards more sustainable consumption (i.e. lower environmental impacts) in the second survey. We find moderately significant change in behavior ($b = -0.212$, $p = .065$, 95% CI $= [-0.437, 0.013]$), only for CO_2 in the Procedural Health treatment, compared to the Control treatment. A very tentative conclusion would be that providing procedural information works better than no information, but only when this information is

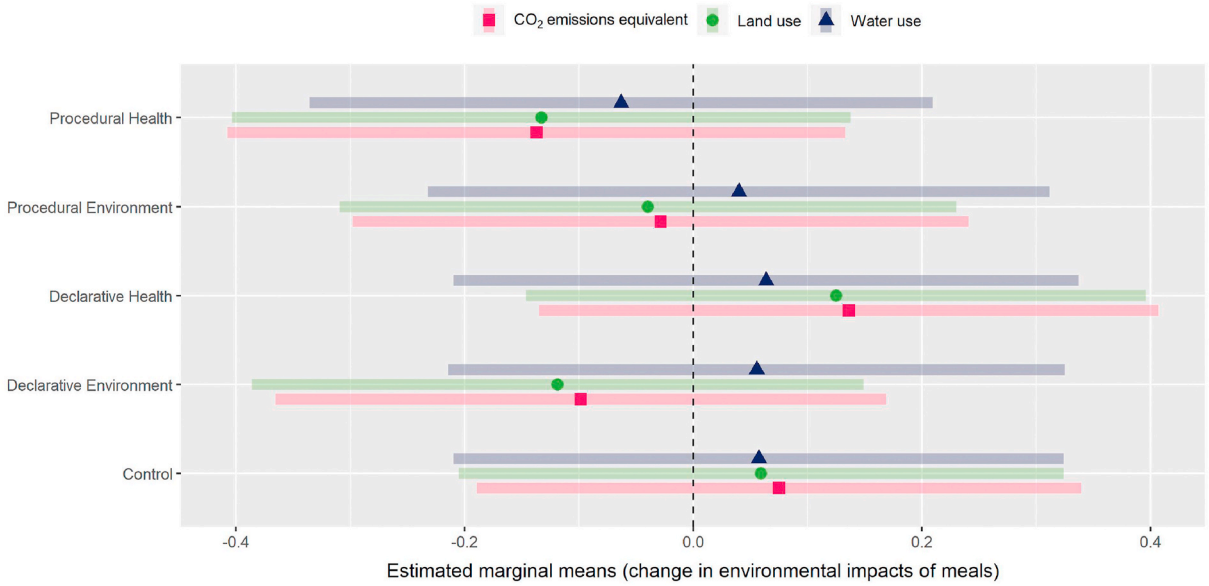

Fig. 4. Estimated marginal means of the change in environmental impacts by treatment and indicator. *Note:* Dotted reference line indicates zero change between survey waves. Markers indicate means, error bars indicate 95% confidence intervals.

Table 3
OLS regression of treatment interactions on change in sustainable behavior.

	DV: Change in environmental impact		
	CO_2	Land	Water
Constant	− 0.181**	− 0.188**	− 0.019
	[− 0.357, − 0.006]	[− 0.362, − 0.013]	[− 0.192, 0.153]
Treatment			
Procedural [ref = Declarative]	0.231**	0.240**	0.008
	[0.002, 0.460]	[0.013, 0.468]	[− 0.218, 0.233]
Health [ref = Environment]	0.064	0.073	− 0.013
	[− 0.163, 0.292]	[− 0.153, 0.300]	[− 0.238, 0.211]
Procedural × Health	− 0.337**	− 0.331**	− 0.114
	[− 0.658, − 0.017]	[− 0.649, − 0.012]	[− 0.429, 0.202]
Diet [ref = No restrictions]			
Dietary restrictions	0.270***	0.262***	0.113
	[0.105, 0.435]	[0.098, 0.427]	[− 0.050, 0.275]
Observations	582	582	582
R^2	0.031	0.030	0.006

Notes: *$p<0.1$; **$p<0.05$; ***$p<0.01$. Dependent variable is the change in environmental impact from Survey 2 to Survey 1. Table reports unstandardized regression coefficients with 95% confidence intervals in square brackets. Model restricted to treatment groups to compare interactions, excluding 151 control group observations. Controls: response time.

about how to prepare a healthier meal. Following a particular diet (such as flexitarian, vegetarian, vegan, etc.) has a strong positive effect across all markers of sustainable food choices. People without dietary restrictions are more likely to move towards ingredients with lower environmental impacts (i.e. they consume more sustainably in the second compared to the first survey) than people with dietary restrictions. This could be explained by the fact that people without dietary restrictions have more options to change to a more sustainable diet, for instance, by reducing meat consumption.

Next, we analyze the effect of the way how information is provided in the interventions by testing the effects of the type of information (declarative vs. procedural) and the type of reported impacts (on health vs. environment) separately and in interaction, while excluding the Control group. Participants in the procedural information treatments were expected to show more sustainable food choices than those in the declarative knowledge conditions (Hypothesis 3). The Control group increased their meal impact in CO_2 and land use between the first and second survey to lesser extent than most groups but more than the Declarative Health group. With respect to water use, the Control group reduced the water impact of their meals more than the other groups.

Table 3 shows that providing procedural information (compared to declarative information) has a negative effect on behavioral change (i.e. they eat more sustainable meals in the second wave) for CO_2 when information concerns health issues ($b = -0.337, p = .039$, 95% CI = [−0.659, −0.016]), but positive when treating environmental issues ($b = 0.231, p = .049$, 95% CI = [0.001,0.460]). This effect re-occurs for land use. For water use, this effect is not significant. Regarding whether respondents are more likely to respond to messages motivated by health compared to those motivated by the environment (Hypothesis 4), we observe no main effect. We expected that information on health impacts would lead to a stronger dietary change, yet this is only the case when health information is provided in procedural form. The fact that we do

not find an effect of information in declarative form could be some sort of ceiling effect, following from the high pre-intervention values of knowledge about health (see Table 1).

Summarizing, we find that messages with procedural information about health impacts of diets can be effective in reducing environmental impacts of food choices. Again, we find a strong positive relationship between dietary restrictions and environmental food impacts (i.e. CO_2 and land use). People with dietary restrictions show a smaller decrease (or even increase) in environmental impacts of their food choices than those without restrictions, which might be explained by the fact that their baseline impact was significantly lower, as shown in Table 2.

4. Discussion and conclusion

Previous research has investigated the role of nutritional knowledge in making healthy food choices (Dickson-Spillmann & Siegrist, 2011; Wardle et al., 2000; Worsley, 2002) and has shown that nutritional knowledge positively and strongly affects healthy eating behavior (Dickson-Spillmann & Siegrist, 2011; Wardle et al., 2000). We are one of the first to perform such an analysis for sustainable food choices. Other than Vermeir and Verbeke (2006) who explored the relationship between knowledge about sustainable food choices and intention to make sustainable choices, we observe actual dietary behavior of a representative sample of consumers. Our study is more related to (Visschers & Siegrist, 2015), who found a small positive correlation between perceived environmental impact of canteen meals and objective CO_2 equivalents of these meals. Here, we find that consumers with greater knowledge about either healthy or sustainable food choices report eating meals with lower environmental impacts. The correlation between pre-intervention knowledge and observed dietary change is significant, albeit weak, and mainly with respect to the CO_2 and land use impacts of food choices. We do not find such a correlation with respect to the impact on water use.

Overall, few respondents were knowledgeable about sustainable food choices, whereas knowledge about healthy food choices seems more widespread in the population. This is in line with insights from our scoping study among students, who showed a lack of knowledge about sustainable food consumption. As expected, the behavioral change was largest for those who did not make sustainable choices in their diet before the intervention. Across conditions and analyses, people without restrictions in their diet are more likely to change their behavior compared to people with dietary restrictions. Obviously, the large share of the population without dietary restrictions (60% of our sample) constitutes the largest potential to reduce the environmental impacts of their food choices, especially by reducing meat consumption. This group should be in the focus of communication measures. Our results show that using short information nudges may lead to a significant impact on behavior, even though the changes are small. More extensive nudges might elicit a larger behavioral change.

To explore how to enhance dietary knowledge and stimulate more sustainable dietary choices, we adopted a sequential mixed-methods design, where a scoping study provided input for the design of an information intervention. Pre-intervention knowledge about healthy and sustainable food choices as well as actual dietary behavior in the form of ingredients of three recently consumed meals were elicited among a representative sample of the Dutch adult population in two waves. Each participant in the first wave was randomly assigned to one of the treatment conditions or was given no information. Dietary choices were measured again in the second survey to observe any differences in response to the information nudges.

The information nudges at the end of the first wave were provided in four different treatment conditions. Respondents either received a message about health or environmental impacts of dietary change, on how to prepare a healthy/sustainable meal (including links to a recipe; procedural information) or the health/sustainability impact of replacing certain ingredients (declarative information). Furthermore, the message was tailored to the self-reported diet, i.e. meat eaters got a different message than vegans, thereby stimulating incremental behavioral changes. The differentiation of the messages according to self-reported dietary restrictions follows the rationale that an information nudge is most effective when it targets the marginal individual (Coffman et al., 2015) and follows the insights from Abrahamse et al. (2007) who show that tailored information is more effective than general messages.

Regarding the information nudges, we observe that after a period of seven days, especially procedural knowledge on how to prepare a healthier meal has the potential to influence actual dietary behavior towards more sustainability. This is a promising result, given that the information nudge was a one-time and rather subtle intervention. The fact that a declarative information nudge had no effect is in line with the results of Campbell-Arvai et al. (2014b), who found no effect of declarative information regarding environmental impact on meal choice in a university canteen study. Providing consumers with concrete ideas how to prepare meals with increased health benefits may be a promising way to trigger behavioral change towards more sustainable diets. This is in line with the findings by Asensio and Delmas (2016) that a health-based framing is more effective than a cost-based framing when nudging household energy savings. Nudges framed by health reasons are focused on individualistic benefits which stimulates individuals' egoistic interest. Asensio and Delmas (2016) compared a health-based nudge with cost-saving message which both focus on personal benefits. Their findings imply that the type of personal benefits matters in how effective the message will be. Our message that focused on personal health benefits (i.e. the declarative health treatment) did not change behavior, but our procedural health treatment activated a behavioral change in the course of one week. The environmental message did not induce such a change, confirming the importance of framing. Even though procedural information on how to prepare a healthier meal stimulates a behavioral change, this study does not clarify on how people changed their behavior. A future study could explore which heuristics are used by people to initiate such a behavioral change.

Many have found a weak or no substantial effect on behavior of providing information unless accompanied by other cues (Ratner et al., 2008; Stern, 1999). Especially concerning habitual behavior, which is often the case in dietary choices, information alone is unlikely to stimulate a behavioral change (Verplanken & Wood, 2006; White et al., 2019). In our experiment, even people in the control condition changed their behavior, and decreased the environmental impact of their meals between the survey waves. This change can be due to an heightened interest in food choices caused by the questions about knowledge or meals. In particular, Verplanken and Wood (2006) show that the timing is very important. Information is much more likely to induce a behavioral change during a period of change than in a regular period. As we have collected our data during the corona crisis, people were undergoing many changes, which could have made them more sensitive towards the information nudge.[14] Whether this is true would need to be tested by repeating the experiment in another period.

Another novelty of our study is the development of a precise way to measure the environmental impacts of single meals. For each meal reported in the intervention study, a weak but positive relationship was found between the observed impact of a meal and the perceived impact of this meal. It appears that people find it difficult to assess the environmental impact of food. It matters how environmental impact is measured. When we take the CO_2 or land use, we detect this negative effect, but for water use, we observe the contrary (a positive effect). Participants who know more about healthy diets are more likely to make food choices that are unsustainable in terms of water use. Diet-related knowledge about the environment does not affect food choices

[14] The survey included a question on whether participants changed their consumption patterns during the lockdown. More than 70% of respondents reported no change in red meat, white meat or dairy consumption.

measured in terms of water use. These findings suggest that the average consumer is better informed about, or cares more about, the CO_2 and land use impacts of food choices, as compared to the impact on water use. A tentative suggestion would be to communicate the impact of certain food choices on water use.

It should be noted that our approach to measure environmental impacts used standardized portion sizes because we were particularly interested in ingredient replacements. A powerful alternative would be to stimulate reduced portion sizes (De Boer et al., 2014; Geier et al., 2006). Further research could combine both approaches, which would also allow for detecting spillover effects (i.e. replacing meat on some days, but compensating with larger portions of meat on the other days of the week). However, introducing portion sizes comes at a cost of complexity in the meal selection tool, which may lead to higher attrition and noisier data.

Little is known about whether behavioral change induced by an intervention will last. Abrahamse et al. (2005) show that providing a specific type of feedback over a prolonged period can be very successful in having a lasting effect on behavior. Moreover, Frey and Rogers (2014) explore various ways to make treatment effects persistent. They conclude that the persistence of a treatment depends on whether the intervention is suited to build psychological habits, whether it changes what and how people think, whether they change the future costs of a certain behavior, or whether they harness external reinforcement of the respective behavior. Our treatment mainly aimed to change what and how people think, which initiated behavior change in the procedural health treatment group. It is plausible that repeated interventions and prolonged treatment would lead to a substantial and lasting change in dietary patterns. A particular promising finding of our study is that even a single health information nudge can motivate people without dietary restrictions (i.e. meat-eaters) to change their diet.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvp.2021.101610.

Author statement

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