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Healthy or not: Influencing attention to bias food choices

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ABSTRACT

Previous work has shown that people are more likely to choose a food item that was cued by an arrow briefly presented before the presentation of two options. This preference for cued over uncued items could be explained by a shift of attention. In the current study, we investigated whether we could nudge people towards making more healthy decisions by manipulating attention using directional cues. First, we created a stimulus set with pictures of Natural and Ultra-Processed Food (NUPF) items, which were rated on several scales, including affective and motivational measures ($n = 160$; the stimuli and ratings are made freely available and make up the new NUPF stimulus database). Second, we asked a different set of participants ($n = 292$) to rate these food items with regards to how much they would like to eat each of the shown items. During the following choice phase, directional cues (i.e., an arrow pointing left or right), and neutral cues (arrows pointing left and right) were presented before participants were given the choice between two food items. Even though the cues were not relevant for task performance and could potentially even guide attention towards non-preferred items, participants chose the cued items more often than uncued or neutral items and were faster in doing so. The cues biased participants choices irrespective of healthiness, suggesting that external cues could potentially be employed to direct attention and to promote healthy decision-making.

1. Introduction

Obesity is a major risk factor for the development of type 2 diabetes and cardiovascular diseases. It has become one of the leading causes of preventable death (Bauer, Briss, Goodman, & Bowman, 2014). In high-income countries, food supplies are dominated by ready-to-eat products (Monteiro et al., 2016), which often consist of ultra-processed foods that increase the risk for diabetes (Fardet, 2016). Processed foods are dense in energy (Small & DiFeliceantonio, 2019), and compared to natural foods they have lower nutritional value and satiety potential (Barr & Wright, 2010; Fardet, 2016). Therefore, promoting the intake of natural foods with higher nutritional value and satiety potential could be an effective way to decrease unhealthy eating behavior. To curb the obesity pandemic, policy makers could use effective tools to motivate people to eat more natural foods. In the current study, we aimed to investigate whether directional cues could be used to promote healthy decision-making behavior. In our analyses, we considered several other factors that are known to influence attention and decision-making (such as desirability, hunger, caloric density, and happiness).

In our everyday lives, we are surrounded by food stimuli, that compete for our attention. Irrespective of whether we work at home or commute, food items are very common in our environment and can draw our attention at any time, for example when we see a passerby eating a delicious sandwich, or our partner opens the fridge. Previous work has suggested that especially food items that we crave will draw our attention (e.g., Kemps & Tiggeman, 2009; Werthmann, Roefs, Nederkoorn & Jansen, 2013), and that these effects can be strengthened by hunger (Piech, Pastorino, Zald, 2010). The majority of studies that have investigated the role of attention in food choices have used variations of the visual probe task (VPT; see for example Lopes, Viacava, & Bizarro, 2015). In the VPT, participants have to identify the location of a target probe (typically a simple visual stimulus, like a dot), while other visual stimuli (e.g., pictures of food) act as cues. The target can be presented at one of several cued locations, and response times to the target serve as a measure of attentional capture by the different cues (see, for example, Doolan, Breslin, Hanna, Murphy, Gallagher, 2014; Pool, Brosch, Delplanque & Sander, 2014). In a food-related VPT, responses are typically faster when the target is presented at the location of the food item that captured attention (Doolan, Breslin, Hanna, Gallagher, 2015), and similarly, distractors signaling food and drink

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rewards have been shown to capture attention in a visual search task (Watson, Vasudevan, Pearson, & Le Pelley, 2020).

Previous studies have shown that both appetitive and aversive stimuli are viewed earlier, with a higher probability, and longer than neutral items (Schomaker & Wittmann, 2017; Schomaker, Walper, Wittmann, & Einhäuser, 2017). The probability and duration that we will look at a certain option are thus affected by subjective value. These types of effects on attention are caused by our previous selection history (i.e., previous experiences with certain stimuli, see Awh, Belopolsky, & Theeuwes, 2012). Attentional capture may differ for different types of food stimuli or between individuals, and an increasing body of literature shows that attentional processes may in fact drive the decision-making process. Experimental studies have shown that we typically dwell longer on an object of our preference and are more likely to choose an item that we viewed longer, suggesting that the relationship between attentional allocation and choice is even causal to some extent (Krajbich, Armel, & Rangel, 2010; Schotter, Berry, McKenzie, & Rayner, 2010; Shimojo, Simion, Shimojo, & Scheier, 2003). For example, when viewing duration is experimentally manipulated, value-based choice behavior is biased towards the items that were shown longer (Armel, Beaumel, & Rangel, 2008; Krajbich et al., 2010). Similar findings have been obtained with more complex decisions, such as moral choices and purchase behavior (Parnamets, et al., 2015; Zhang, Wedel and Pieters, 2009).

Attention towards options is not only influenced by our previous experience but can also be influenced by top-down and bottom-up factors (Theeuwes, 2010), which also play a guiding role in the decision-making process (Orquin & Mueller Loose, 2013; Vriens, Vidden, Schomaker, 2020). Top-down factors include an individual's goals (Awh, Belopolsky, & Theeuwes, 2012), while bottom-up factors may include stimulus features such as color, brightness, orientation, position, size, etc. (Itti & Koch, 2000; Itti, Koch, & Niebur, 1998; Milosavljevic, Navalpakkam, Koch, & Rangel, 2012; Schomaker, Walper, Wittmann, & Einhäuser, 2017; Theeuwes, 1991, 1992). While top-down factors may be influenced by task instructions, bottom-up factors are defined by the physical characteristics of a stimulus with respect to its background, determining its visual salience. A red apple, for example, will stand out amongst green apples, but not so much amongst other red apples. Interestingly, several previous studies have shown that visual salience, through its effects on attention, can influence decision-making, biasing choice behavior towards more visually salient options (Milosavljevic et al., 2012). These laboratory findings have been shown to be generalizable to more realistic settings, such as the supermarket (Gidlöf, Anikin, Lingonblad, & Wallin, 2017). Attention thus seems to play a crucial role in the value-based comparator process underlying decision-making (Krajbich & Rangel, 2011), however, the effects of attention-directing cues in food-related choices remain under-researched. One previous study suggested that attentional capture by certain food stimuli may be overruled by attention directing cues. In that study, *task-irrelevant* cues influenced choices between snacks through their effect on attention (Vriens, Vidden & Schomaker, 2020). On trials on which attention was manipulated, the cues consisted of directional arrows, that are believed to elicit shifts of spatial attention (Awh, et al., 2012; Posner, 1980; Jonides, 1981). Participants were faster and more inclined to choose a cued compared to a non-cued snack item. In the current study, we aimed to investigate whether attention-directing cues can be used to promote healthy decision-making.

1.1. Factors that could influence food choices through attention: Effects of hunger and happiness

Previous studies have shown that hunger influences attentional allocation. For example, Mogg, Bradley, Hyare, and Lee (1998) observed that, unlike satiated people, hungry people more frequently shifted their attention towards food-related words than transport-related words. These findings were supported by an event-related potential (ERP) study, which further suggested that hunger increases attention for food-related pictures (Stockburger, Schmälzle, Flaisch, Bublatzky, & Schupp, 2009). Similarly, hunger has been shown to increase attention towards sweets and candy (Gearhardt, Treat, Hollingworth, & Corbin, 2012). Hunger may also increase the rewarding properties of food: One study showed that high-calorie foods are experienced as more rewarding after 24 h of food deprivation (Siep et al., 2009). Hunger does not only influence the subjective value of food, it can also bias cognitive control processes, as shown in a study where hungry people were impaired at inhibiting responses towards food-related distractor words in a go/no-go task (Loeber, Grosshans, Herpertz, Kiefer, & Herpertz, 2013).

Also, happiness may influence decision-making processes. Otake and Kato (2016) observed that individuals with high versus low levels of subjective happiness experienced more intense positive emotions when they looked at food pictures. Positive affect can also facilitate response speed: Studer and Winkelmann (2014) found that a good mood was associated with intuitive, fast responses on a happiness questionnaire. Moreover, people in a negative mood have been shown to focus more on short-term consequences of eating, including mood improvement and taste, which is why they chose unhealthy comfort foods high in fat, sugar, and salt (Gardner, Wansink, Kim, & Park, 2014). In contrast, people in a positive mood attached more importance to long-term goals related to health, and therefore they preferred nutrient-rich, healthy foods to unhealthy foods. However, studies have suggested that happiness can also prompt unhealthy choices: People who believe that their positive mood is fleeting might indulge themselves with unhealthy food to maintain the good mood (Labroo and Mukhopadhyay, 2009), and emotional eaters increase their food consumption when in a positive mood (Bongers, Jansen, Havermans, Roefs, & Nederkoorn, 2013). The affective congruency hypothesis suggests that one's attention is drawn to affect-consistent features, which may explain why positive emotions might prompt craving for sweet-tasting food (Gardner et al., 2014), and restrained eaters might increase their food consumption as a response to positive emotional arousal (Cools, Schotte, & McNally, 1992). In the current study, we aimed to investigate if attention manipulation can influence choices between food items. Since both hunger and happiness may influence choice behavior as well, we include measures of both in our regression models. We expected that affect would influence choices and response speed through the effects on attention but would not interact with the effects of our directional cues (see for example Schomaker, Walper, Wittmann, & Einhäuser, 2017). In contrast, we expected that hunger would lead to faster responses and would potentiate the effects of directional cues, further biasing attention towards cued locations, and potentially influencing choices as a result (Cheung, Kroese, Fennis, & De Ridder, 2017).

1.2. Healthiness of processed versus non-processed foods

For the purpose of the current study, we created a set of images of food items that varied in terms of the level of processing, including natural and ultra-processed foods (these now make up the Natural & Ultra-Processed Foods [NUPF] database). Ultra-processed foods – i.e., foods that have been processed using various techniques at different stages of preparation – are typically dense in energy and compared to natural foods have lower nutritional value and satiety potential (Small & DiFeliceantonio, 2019; Barr & Wright, 2010; Fardet, 2016). Moreover, ultra-processed foods are associated with obesity and non-communicable diseases (Monteiro, Moubarac, Levy, Cannella, da Costa Louzada & Cannon, 2018; Rauber, da Costa Louzada, Steele, Millett, Monteiro & Levy, 2018). Therefore, in the NUPF database stimuli used in the present study, healthiness was defined by the level of food processing. We used two categories of food items: (1) unprocessed (healthy) and (2) ultra-processed (unhealthy). Following the NOVA classification that categorizes foods based on the amount and purpose of the biological, chemical, and physical processing they received (Monteiro et al., 2016), our first category consisted of natural foods, including plant and animal products such as fruits, nuts, and eggs. Our second category consisted of ultra-processed products, such as chocolate, cookies, and crisps, items often containing additives, including non-sugar sweetener and artificial colorant.

1.3. Present study: Manipulating attention to influence healthy decision-making

Many studies investigating the role of attention in decision-making do not explicitly manipulate visual attention, but rather vary exposure durations to the different options. For example by showing some items longer than others (Armel et al., 2008; Krajbich et al., 2010), manipulating the timing of the decision (Pärnamets et al., 2015), taking differences in visual salience into account (Chen, Mihalas, Niebur, & Stuphorn, 2013; Milosavljevic et al., 2012), or comparing attentional capture to different food stimuli (as in the studies that use the VPT). Our previous study confirmed that attention guided with cues can also bias choices (Vriens, Vidden & Schomaker, 2020).

The current study aimed to investigate whether an attentional bias induced by visual directional cues could influence food choices (as in Vriens, et al., 2020). We were specifically interested to see if people could be nudged toward healthy rather than unhealthy options. First, we created a new set of food stimuli by photographing (ultra-)processed (unhealthy) and non-processed (healthy) food items on a grey background (creating the NUPF database). Second, we obtained assessments on motivational factors including approach/avoid and desirability ratings, affective factors including valence and arousal and additional measures such as recognizability, popularity and perceived healthiness (following a similar procedure as in Schomaker, Rau, Einhauser, & Wittmann, 2017). Finally, a new group of participants rated the stimuli in terms of desirability (i.e., “How much they would like to eat this item?”) using a slider (from “not at all” to “very much”) in a rating phase. In the following choice phase, participants chose between two food items that could be either healthy (unprocessed to processed [most items were natural, with the exception of cheese, that may be considered a processed food]) or unhealthy (ultra-processed) types of food. All combinations (healthy-healthy; healthy-unhealthy; unhealthy-unhealthy) could occur. The items were preceded by a directional (left or right), or neutral (left and right) arrow, or no cue at all. It was expected that the directional cues would result in shifts of attention (Posner, 1980), nudging participants towards the cued rather than the uncued option. Both hunger and happiness measures were used as predictors in the analyses of the food choices. Our design allowed us to investigate whether directional cues have the potential to nudge people towards healthy food choices.

2. Methods

2.1. General study design

This study consisted of two parts. First, we photographed 40 natural and ultra-processed foods on a grey background and obtained *ratings* from two groups of participants. The first group ($n = 70$) rated the stimuli on approachability, desirability, popularity, and healthiness. The second group ($n = 90$) rated the same items on valence, arousal, and recognizability. The images and ratings now make up the NUPF database. Second, a different group of participants did a *food choice experiment*. In the first phase of this experiment, participants rated the desirability of the food items, and in the following phase, they made choices between food items.

Experiment 1: Food ratings for the NUPF database

2.2. Participants

All participants gave informed consent by checking a box prior to participation. All food items were first rated on seven different scales. To limit the duration required to finish these *food ratings*, we collected data from two groups of participants who rated all the objects on a subset of the scales (see Table 1). For the first *food rating* 70 and for the second 90 different participants were recruited. Recruitment was done via online fora and social media channels of Leiden University. Participants participated voluntarily and could receive course credit as compensation. Both experiments 1 and 2 were approved by the Psychology Research Ethics Committee (CEP) of the Faculty of Social Sciences at the department of Psychology at Leiden University, the Netherlands (reference: CEP19-1128/564).

2.3. Procedure

The food ratings were obtained via an online survey using Qualtrics. Participants were first given a brief questionnaire description and gave informed consent by checking a box. Forty images of food items were rated in an online Qualtrics questionnaire. The first group of participants (*food ratings I)* were asked to rate each item on 7-point Likert scales on Approach/Avoid (“Would you like to approach or avoid this food item?”) from “Avoid” to “Approach”), Desirability (“How much would you like to eat this item?”) from “Not at all” to “Very much”), Popularity (“How often do you eat this or a similar item?”) from “Not at all” to “Very often”, and Healthiness (“How healthy do you think this item is?”) from “Not at all” to “Very”. The second group of new participants (*food ratings II*) were asked to rate the same items on Recognizability (“Do you recognize this food item?”) from “Not at all” to “Very familiar”, Valence (“Does this food item elicit any positive or negative emotions?”) from “Negative” to “Positive”, and Arousal (“Does this item make you calm or aroused?”) from “Calm” to “Aroused”. The food ratings I took around 15–20 min, and the food ratings II took about 10 min.

Table 1
Participant details and scales rated per group in the NUPF rating experiment. Approach/Avoid (“Would you like to approach or avoid this food item?” from “Avoid” to “Approach”), Desirability (“How much would you like to eat this food item?” from “Not at all” to “Very much”), Popularity (“How often do you eat this or a very similar food item?” from “Not at all” to “Very often”), Healthiness (“How healthy do you think this food item is?” from “Not at all” to “Very”), Recognizability (“Do you recognize this food item?” from “Not at all” to “Very familiar”), Valence (“Does this food item elicit positive or negative emotions?” from “Negative” to “Positive”), Arousal (“Does this food item make you calm or aroused?” from “Calm” to “Aroused”) and subjective personal health (“How would you describe your current health?” from “Very poor” to “Excellent”) were all rated on a 7-point Likert scale (from 1 to 7).

	Food ratings group I	**Food ratings group II**
	$n = 70$	$n = 90$
Ratings	Approach/Avoid; Desirability; Popularity; Healthiness	Recognizability; Valence; Arousal
Mean age (in years)	29.3	34.1
Sex	47 females; 23 males	43 females; 47 males
Diet	7.14% pescatarians 20% vegetarians 7.14% vegans 1.43% gluten-free 1.43% paleo 8.57 a non-listed diet 54.29 following no diet	2.22% pescatarians 13.33 vegetarians 5.56% vegans 1.11% gluten-free 1.11% paleo 16.56% a non-listed diet 61.11% following no diet
Weight	52.86% trying to keep their weight 5.71% trying to gain weight 41.42% trying to lose weight	41.11% trying to keep their weight 8.89% trying to gain weight 44.44% trying to lose weight
Subjective personal health	4.6 (SD = 1.2)	4.9 (SD = 1.3)

2.4. Stimuli and apparatus

A new set of forty food stimuli was created by photographing processed (unhealthy) and non-processed (healthy) food items on a grey background. The newly created stimuli now make up the NUPF database (the mean ratings per food item can also be found here: https://doi.org/10.5281/zenodo.4601555). Packaged food items were taken out of their package to reduce the effects of product marketing (either regarding strategically designed packaging, but also regarding brand recognition) and attentional effects towards text. Food ratings were obtained for all 40 items using Qualtrics, and all served as stimuli used in Experiment 2.

3. Results experiment 1

Appendix A shows all NUPF database images as they were shown to participants at the beginning of the food choice experiment. The mean ratings for approach/avoid, desirability, valence, arousal, popularity, recognizability, and healthiness as obtained in the rating experiment are shown in Fig. 1. Healthy items received higher approach and desirability scores than unhealthy items, $t(69) = 12.47$, $p < .001$ and $t(69) = 9.52$, $p < .001$ respectively. Also, valence and arousal ratings were higher for healthy compared to unhealthy items, $t(69) = 9.10$, $p < .001$ and $t(69) = 10.72$, $p < .001$ respectively. Participants also indicated to eat the healthy items more often (i.e., the popularity rating), $t(69) = 17.71$, $p < .001$ and to recognize the healthy items better than the unhealthy items, $t(69) = 11.59$, $p < .001$. As expected, the healthy items were evaluated as more healthy than the unhealthy items, $t(69) = 10.7$, $p < .001$. All effects survived Bonferroni correction. Information regarding the stimuli (calorie density, calories per portion, etc.) can be found in Appendix C. Appendix d shows the ratings per scale for each food item. The stimuli and ratings obtained in these experiments make up the natural and Ultra-Processed foods (NUPF) database that can be downloaded and used free of charge (https://doi.org/10.5281/zenodo.4601555).

Experiment 2: Main food choice experiment

3.1. Participants

For the main *food choice experiment,* 312 different participants (adults age > 17 from English-speaking countries including Australia, New Zealand, United States of America, and Canada) were recruited through Amazon MTurk, but only 292 participants finished the task. Further inclusion criteria for the food choice task analyses were the use of both response keys (resulting in the exclusion of six participants) and choosing at least 1 item for all conditions (resulting in the exclusion of 70 participants), leading to a final sample of 216 participants. For the trial-by-trial regression analyses, data from all participants was included. Unfortunately, the link between our food choice experiment and the following questionnaire in Qualtrics did not work properly, and therefore the demographics of the MTurk participants are unknown (however, for general demographic info of typical MTurk participants, see Burnham, Le, & Piedmont, 2018). Participants were given 1.5 USD as compensation for participating in the experiment.

3.2. Procedure

For this phase data was also collected online. Participants in the food choice experiment gave informed consent via a keyboard response. To improve the recognizability of the food items, the participants were first shown a menu where all food items and labels were shown. This menu can be found in Appendix A. Task instructions were given on the screen. The main experimental task consisted of a rating and a choice phase. Fig. 2 shows example trials of both phases. During the rating phase, participants were asked to rate the desirability of each item by indicating how much they would like to eat each of the 40 food items on a 7-point Likert scale going from not at all to very much. Items were pre-categorized into two categories on basis of whether they were ultra-processed or natural unprocessed foods. As natural foods are generally believed to be healthier, we will refer to the unprocessed items as "healthy", and the processed items as "unhealthy".

The experiment started with the presentation of a menu, on which all food items were shown with labels, to familiarize participants with the possible options and make sure that items that were harder to recognize would be identifiable during the task. Then participants rated their happiness on a 9-point scale (from "depressed" to "happy") and then their hunger on a 7-point scale (from "not at all" to "very"). During the rating phase, each food item was presented for 2000 ms, after which a fixation cross was presented for 500 ms. After fixation presentation, the question "How much would you like to eat this item?" and the corresponding 7-point Likert scale was shown until a response was recorded. All 40 food items were presented in a random fashion. After the rating phase, the food items were shown again in the subsequent choice phase and could occur in a combination of a healthy and an unhealthy, two healthy or two unhealthy items. There were 60 trials with healthy and unhealthy items, with equal probability for a healthy/unhealthy item to occur on the left or right. There were 30 trials with two healthy items and 30 trials with two unhealthy items.

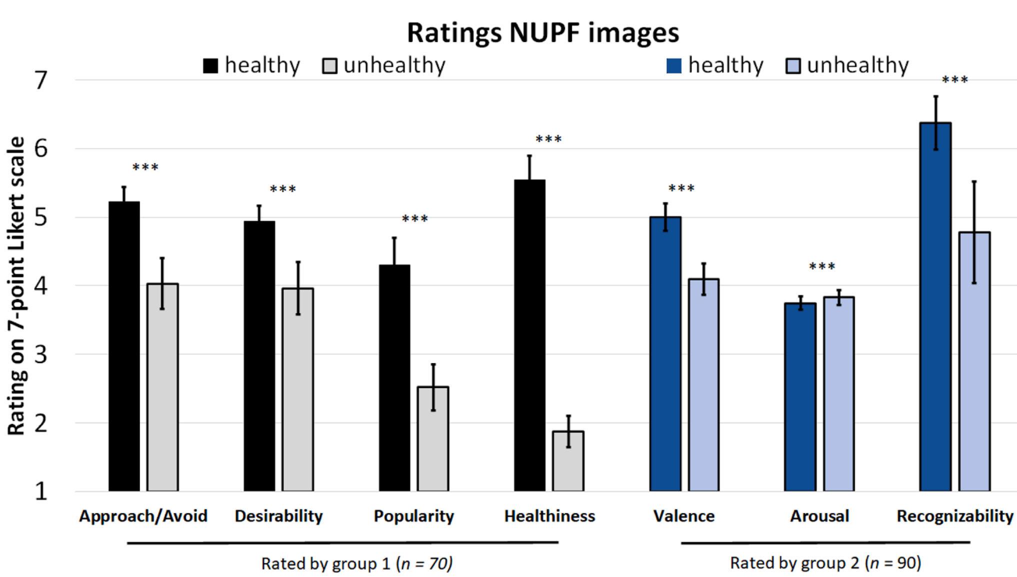

Fig. 1. Mean ratings for the Natural and Ultra-Processed Food (NUPF) images. Our food images were rated by two groups of participants (to limit the length of the survey) on seven scales. The first group (n = 70) rated the stimuli on approachability (approach/avoid), desirability, popularity, and healthiness. The second group (n = 90) rated the same items on valence, arousal, and recognizability. The stimuli and ratings make up the NUPF database which can be downloaded for free (https://doi.org/10.5281/zenodo.4601555). Mean ratings are shown for food items that were defined as healthy (natural) and unhealthy (ultra-processed) in our food choice experiment. Error bars reflect standard deviations.

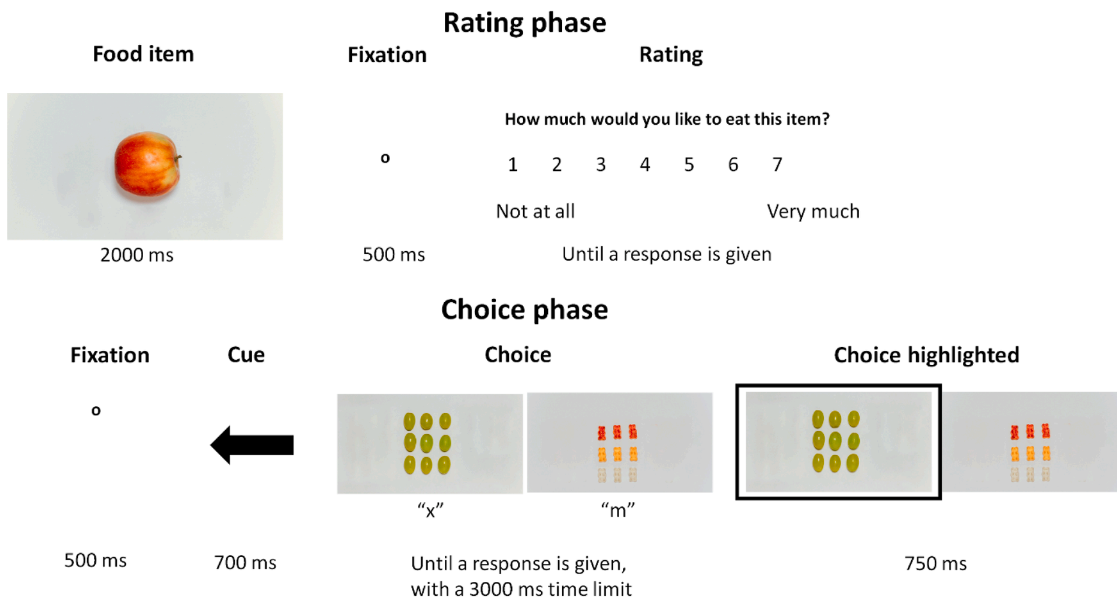

Fig. 2. Example trial from the rating phase (top) and choice phase (bottom). All 40 food items were presented and rated on their desirability during the rating phase. On each trial, participants were asked to indicate how much they would like to eat each item shown on a 7-point Likert scale. Trials during the choice phase started with a central fixation dot, followed by a left- (as shown in the figure), right-, or neutral-pointing arrow (i.e., an arrow pointing both left and right). After cue presentation, items were presented alongside each other, and participants were instructed to choose their item of preference. A response could be given in a 3000 ms time-window, after which the trial timed-out, and the next trial was initiated.

All items and item pairs were presented in a random sequence in both the rating and choice phases. A trial during the choice phase started with a 500 ms central fixation, followed by a cue presented for a duration of 700 ms. There were three types of cues: One pointing to the left, one to the right, and one consisting of two arrows pointing left and right (i.e., a neutral cue). After cue presentation, two food items were presented to the left and right of fixation. Participants were instructed to choose their preferred item. To increase the likelihood that attention effects could play out, participants were instructed to choose the item of their preference, but also to not deliberate too long, as there would be a time-out if responses were too slow. In a previous study, using a similar design we observed no differences in main experimental findings between experiments with a response time limit of 1500 ms or no time limit (Vriens, Vidden, & Schomaker, 2020). Participants, however, had difficulties responding on time on > 30% of trials for the 1500 ms time limit, which is why we now set the response time limit to 3000 ms. A new trial was initiated once a response was given, or when no valid response was given within the time limit. A chosen object was highlighted by a black box that was presented for 750 ms, to confirm the participant's choice. The entire experimental procedure took about 20 min.

3.3. Stimuli and apparatus

The food choice experiment was programmed and stimuli presented using OpenSesame version 3.1 (Mathôt, Schreij, & Theeuwes, 2012) and presented using OpenSesameWeb. The 40 food pictures rated in Experiment 1 served as the options in Experiment 2. The experiment was hosted on a virtual private server using JATOS.

3.4. Statistical analyses

First, the approach/avoid, desirability, valence, arousal, popularity, recognizability and healthiness were compared for the categorically defined healthy and unhealthy food items using paired *t*-tests. Bonferroni-correction was performed to correct for multiple comparisons.

For the food choice experiment, choices were labeled 'cued' when participants chose a left object when a cue pointing to the left, or a right object when a cue pointing to the right was presented. In contrast, choices were labeled 'uncued' when participants chose a left object when a rightward pointing cue, or a right object when a leftward pointing cue was presented. For neutral cue trials, data for left and right chosen objects were collapsed.

Response times (in milliseconds) for trials with a healthy and unhealthy option during the choice phase were analyzed with a 3*2 repeated-measures ANOVA with cue (uncued; neutral; cued) and healthiness (healthy; unhealthy) of the *chosen* item as within-subjects factors. Response times were thus calculated for each combination of healthiness and cue type of the chosen item, leading to six conditions (i.e., cued healthy; cued unhealthy; neutral healthy; neutral unhealthy; uncued healthy; uncued unhealthy). To compare the response times for the different trial types an additional repeated-measures ANOVA was performed with the trial type (healthy & healthy; healthy & unhealthy; unhealthy & unhealthy) as a within-subjects factor. For this analysis, response time data was collapsed over healthiness and cue conditions. Note that these analyses depended on the choices that were made by the participants during this phase, and it was possible that certain item types were never chosen (e.g., uncued unhealthy items), resulting in variable degrees of freedom for these analyses. For all response time analyses, response times > 2,000 ms were excluded.

We observed differences in recognizability between the healthy and unhealthy food items. As this could potentially have influenced response times in the food choice experiment, we ran the same ANOVAs for response times as described in the previous paragraph, but only including trials for which the chosen item had a Recognizability rating of > 5. The results of these tests are reported in Appendix B.

The proportion of choices was calculated by dividing the number of choices per choice type (e.g., cued healthy) by the total number of trials for that trial type (i.e., trials with a healthy and unhealthy option). Note, on trials with a directional cue, participants made a binary decision between a cued and uncued item, which led to a potential violation of the assumption of independence. Therefore, we could not make a direct comparison between cued and uncued trials for a certain trial type (e.g., trials with a healthy and unhealthy item). To investigate the effects of healthiness we analyzed the trials with a healthy and unhealthy option, but healthy and unhealthy choices on these trials were also dependent.

To deal with these issues of dependence we ran separate *t*-tests to investigate the effects of cue type and healthiness. More precisely, the effects of cue on the proportion of choices was investigated with six *t*-tests comparing choices for different cues for healthy and unhealthy choices separately: 1. healthy cued vs healthy neutral; 2. healthy neutral vs healthy uncued; 3. healthy cued vs healthy uncued; 4. unhealthy cued vs unhealthy neutral; 5. unhealthy neutral vs unhealthy uncued; 6. unhealthy cued vs unhealthy uncued. The effects of healthiness were investigated with three separate t-tests, comparing healthy and unhealthy choices per cue type (1. cued; 2. neutral; 3. uncued). We used Bonferroni correction for multiple testing (for cue: α / 6; for healthiness α / 3).

3.5. GL(M)Ms

In a first model (model 1) the effects of hunger, happiness, and attention (as measured by response times) were entered into a generalized logistic mixed model (GLMM) to predict healthy choices (healthy chosen = 1; unhealthy chosen = 0). Hunger, happiness, and response time were fixed-effect predictors, while subject was treated as a random-effects predictor. Variance inflation factors were all < 5 (response time: 1.20; hunger: 3.09; happiness: 3.26) suggesting low multicollinearity.

A second model (model 2) was used to investigate factors that influenced response times. All factors that were expected to influence attention were included: Value, calorie density and portion calories of the chosen item, and individuals' reports of hunger and happiness were entered as fixed-effect predictors in a general linear model (GLM). Value is based on the individuals' Desirability ratings ("How much would you like to eat this item?") of the items during the rating phase. In contrast with the portion calories, calorie density reflects the calorie content of the food item relative to its weight - in this case, for a 100-gram portion. Variance inflation factors were all < 5 (value: 1.04; calorie density: 1.35; portion calories: 1.21; hunger: 3.31; happiness: 3.10) suggesting low multicollinearity.

For both models, the input variables were centered to reduce the effects of collinearity, while not affecting the shape of the distributions. The models were computed using the statistical package R (version 3.2.2; R Core Team, 2015) using the lme4 R package (Bates, Mächler, Bolker, & Walker, 2014) version 1.1.7 and the glm and glmer functions. During the choice phase, a response time limit was set to 3,000 ms, but data showed that on a few trials this time-out did not work. Therefore, trials with response latencies > 3,000 ms were excluded post-hoc. Following the central limit theorem, we assumed normality for our relatively large sample (Hogg, Tanis, & Zimmerman, 1977). We checked residuals versus fitted data and observed no abnormalities (residual plot with a horizontal line, close to zero), suggesting a linear model would be suitable. Probably due to the removal of slow responses no outliers were identified when calculating Cook's distance (all values < 1). For model 2 homoscedasticity could not be assumed, as suggested by a significant Breusch Pagan test (p = .027). To correct for this violation, we built a new model with Box-Cox transformation. A Breusch Pagan test confirmed that the Box-Cox transformation was successful in reducing heteroscedasticity (p > .05). Results reported for model 2 are on the transformed data.

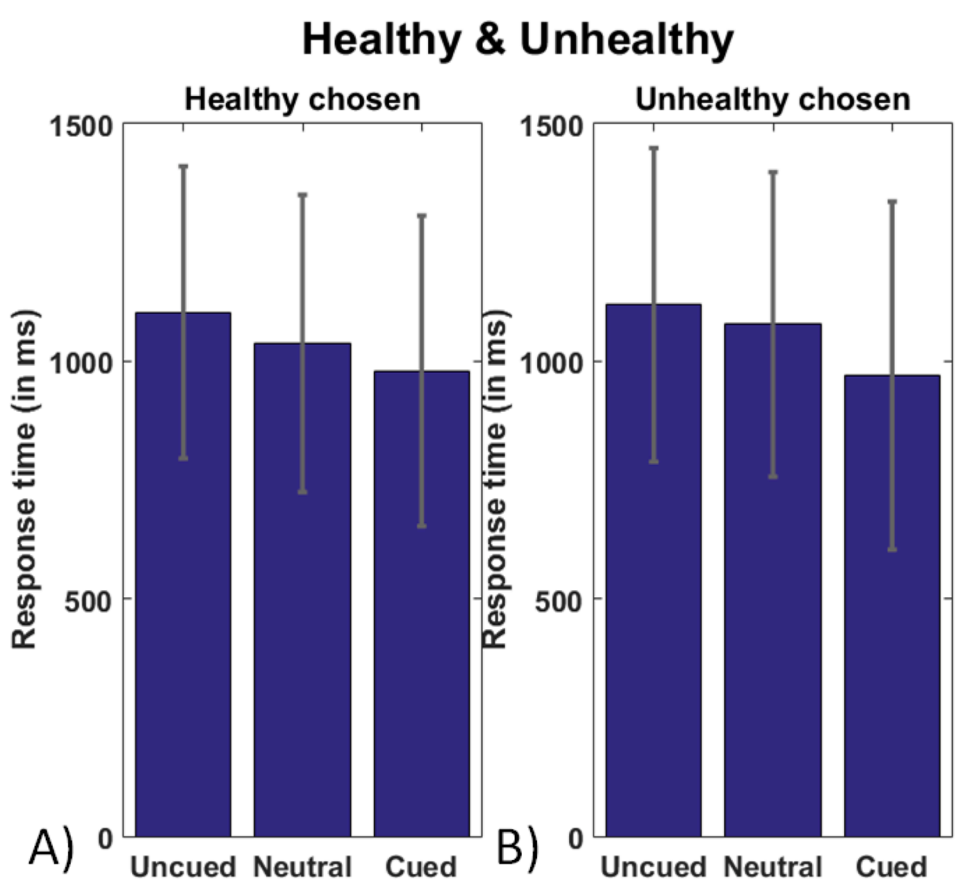

Fig. 3. Mean response times (in milliseconds) during the choice phase for trials on which a healthy and unhealthy item were shown. The left panel shows response times per cue type (uncued, neutral, cued) when a healthy item was chosen and the right panel when an unhealthy item was chosen. Note, for the statistical analyses, trials with left and right responses were collapsed per cue type. Error bars reflect standard deviations.

4. Results experiment 2

4.1. Response times

Fig. 3 shows the mean response times per cue type (left, neutral, right) for trials with a healthy and an unhealthy item. Fig. 4 shows the mean response times per cue type (left, neutral, right) for trials with two healthy or two unhealthy items. The repeated-measures ANOVA investigating the effect of cue type and healthiness of the chosen item on trials with a healthy and unhealthy option showed that cue type affected response times, $F(2,428) = 18.64$, $p < .001$, $\eta^2 = 0.08$. Follow-up contrasts suggested that response times were faster for cued versus uncued choices, $F(1, 214) = 26.20$, $p < .001$, $\eta^2 = 0.11$, and faster for cued versus neutrally cued choices, $F(1, 214) = 7.67$, $p = .006$, $\eta^2 = 0.04$. Responses were also faster for neutral compared to uncued choices, $F(1, 214) = 16.50$, $p < .001$, $\eta^2 = 0.07$. Response times did not differ between healthy and unhealthy choices ($p = .128$), nor did healthiness and cue interact ($p = .747$).

A separate repeated-measures ANOVA suggested that trial type (healthy & healthy; unhealthy & healthy; unhealthy & unhealthy) influenced response times, $F(2, 608) = 3.79$, $p = .023$, $\eta^2 = 0.12$. Follow-up contrasts showed that responses were slower on trials with two unhealthy options than on trials with two healthy options, $F(1, 304) = 4.40$, $p = .037$, $\eta^2 = 0.01$, or one healthy and one unhealthy option, $F(1, 304) = 6.72$, $p = .010$, $\eta^2 = 0.02$, while trials with two healthy options did not differ from trials with a healthy and unhealthy option ($p = .693$).

4.2. Choice behavior

4.2.1. Effects of cue

Fig. 5 shows the mean proportion of choices per trial type (healthy-healthy; healthy-unhealthy; unhealthy-unhealthy) per cue type. Participants more often chose a healthy cued versus neutrally cued or uncued healthy item, $t(291) = 9.61$, $p < .001$ and $t(291) = 10.21$, $p < .001$ respectively. Neutrally cued healthy items were also chosen more often than uncued healthy items, $t(291) = 5.96$, $p < .001$. Similarly, participants more often chose an unhealthy cued versus neutrally cued or uncued unhealthy item, $t(291) = 5.85$, $p < .001$ and $t(291) = 10.04$, $p < .001$ respectively, while neutrally cued unhealthy items were chosen more often than uncued unhealthy items, $t(291) = 9.19$, $p < .001$. All tests survived Bonferroni correction.

4.2.2. Effects of healthiness

A cued healthy item was chosen more often than a cued unhealthy item, $t(291) = 3.29$, $p = .001$. Similarly, neutrally cued healthy items were chosen more often than neutrally cued unhealthy items, $t(291) = 2.59$, $p = .010$ and uncued healthy items were chosen more often than uncued unhealthy items, $t(291) = 3.26$, $p = .001$. These tests also survived Bonferroni correction.

4.2.3. Desirability

We also looked at the subjective desirability of the chosen versus unchosen items, based on the "How much would you like to eat this item" during the rating phase. Chosen items had a similar rating (mean = 4.10; SD = 2.10) than non-chosen items (mean = 4.06; SD = 2.10; p-value = 0.142). The effect of value on choice is further investigated

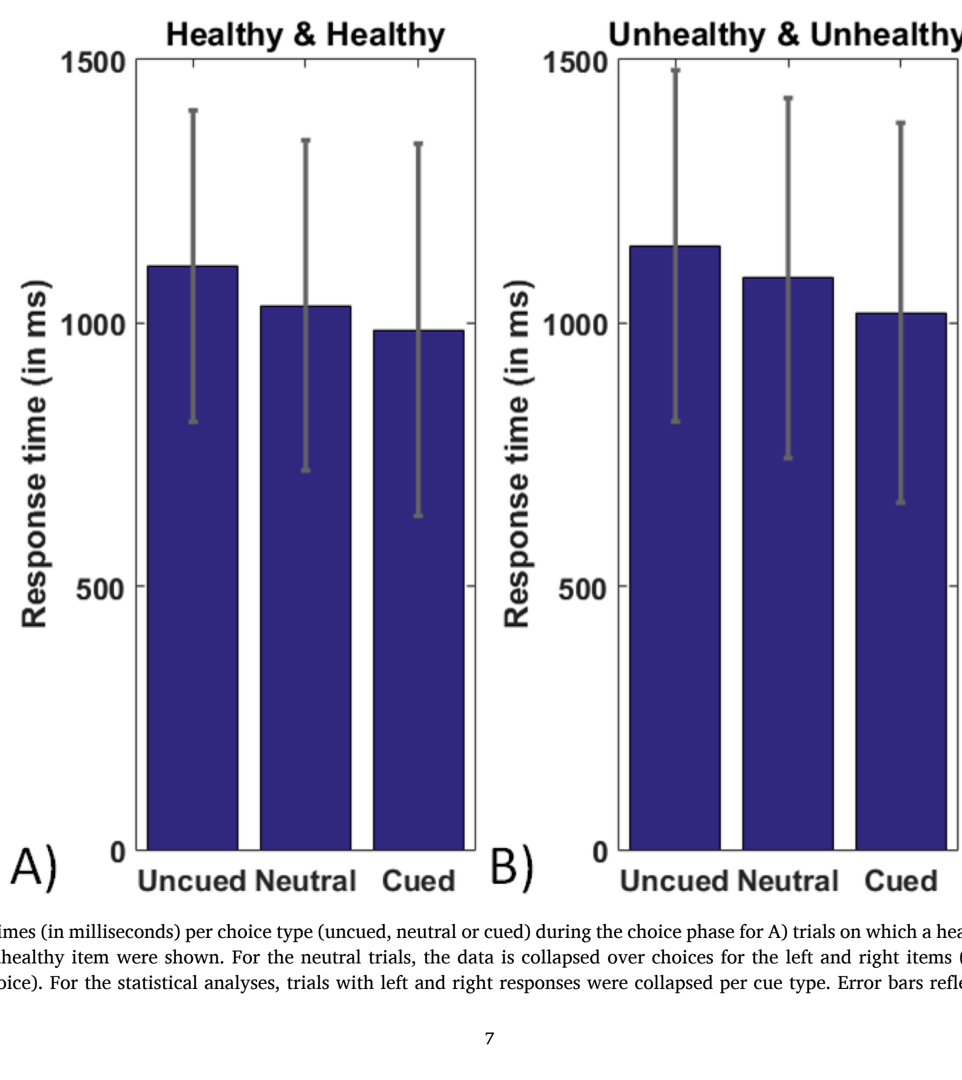

Fig. 4. Mean response times (in milliseconds) per choice type (uncued, neutral or cued) during the choice phase for A) trials on which a healthy and healthy item and B) an unhealthy and unhealthy item were shown. For the neutral trials, the data is collapsed over choices for the left and right items (as either choice could be considered a neutral choice). For the statistical analyses, trials with left and right responses were collapsed per cue type. Error bars reflect standard deviations.

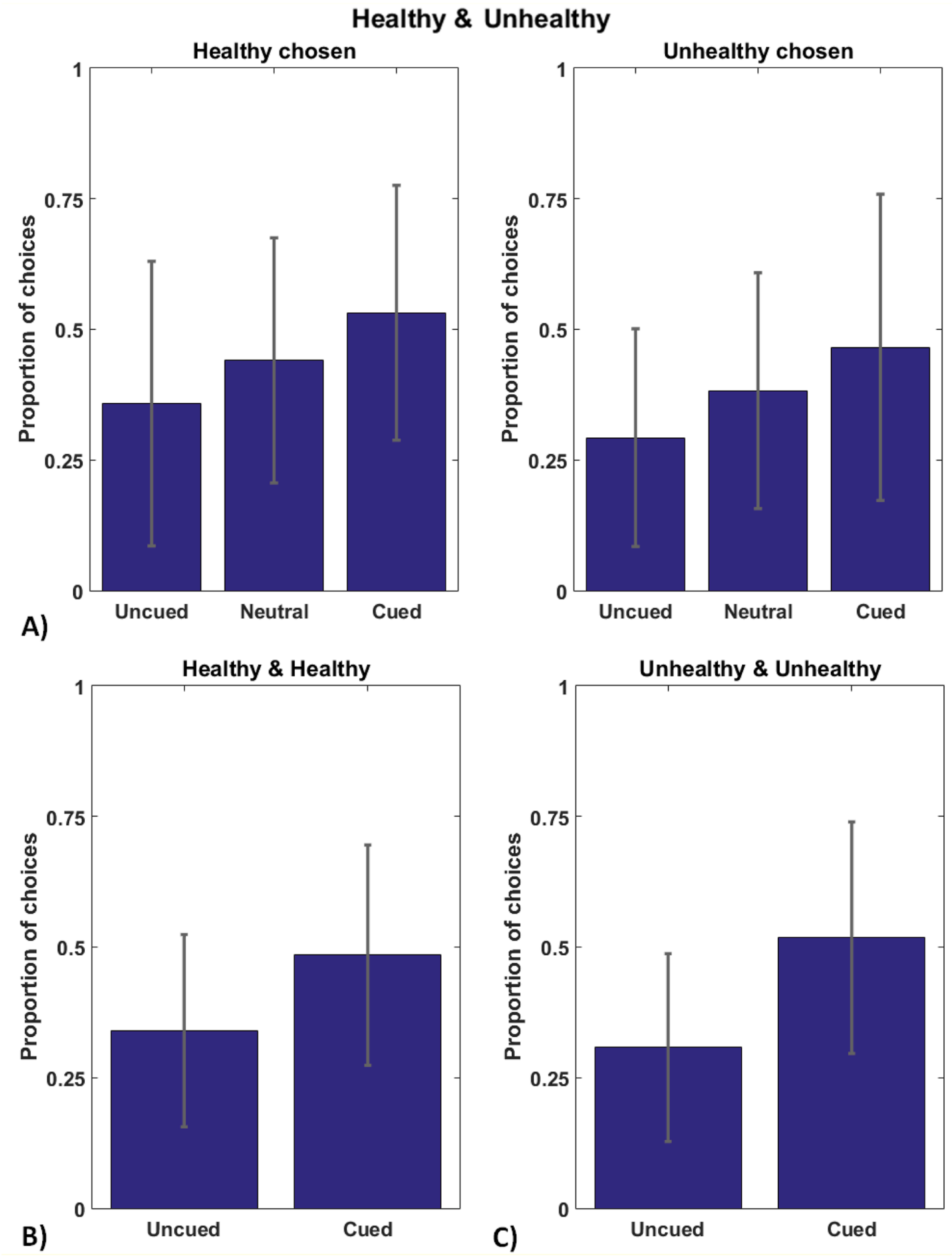

Fig. 5. Mean proportion of choices per combination of A) healthy and unhealthy, B) healthy and healthy, and C) unhealthy and unhealthy items per cue type (uncued; neutral, cued). Error bars reflect standard deviations.

using a generalized logistic mixed model (see below).

4.3. GLMm

The mean hunger rating was 4.27 (SD = 1.88) and the mean happiness rating was 5.24 (SD = 2.01). A GLMM was used to further investigate the effects of attention (as measured by response times during the choice phase), hunger and happiness (see model 1 in Table 2). Response times, hunger and happiness ratings were fixed effects predictors, while subject number was added as a random factor. Response times did not predict the likelihood of healthy choices, and hunger and happiness were both associated with lower chances of choosing a healthy item.

An additional GLM was used to investigate the factors influencing

Table 2
Model 1: GLMM results for a model predicting healthy choices for trials on which a healthy and unhealthy item were presented for trials with directional and neutral cues. The b-value reflects the regressors' slope (i.e., beta). Significant predictors are shown in bold.

		b-value	SE	*z*-value	*p*-value
Observations	*272*				
Intercept		**4.94**	**1.16**	**4.25**	**< 0.001**
Response time		−1.47	< 0.001	−0.04	0.968
Hunger		**−6.07**	**0.10**	**−5.54**	**< 0.001**
Happiness		**−4.57**	**0.13**	**−3.57**	**< 0.001**

response times during the choice phase, with value, calorie density and portion calories of the chosen item, hunger and happiness as predictors and subject as a random factor. See model 2 in Table 3 for the results of this model. Hunger, happiness, and portion calories were associated with faster response times while increasing calorie density was associated with slower responses. Value (i.e., desirability) did not influence response times.

5. Discussion

Results from a recent study showed that attentional manipulation can influence food choices in a binary decision-making task (Vriens, Vidden & Schomaker, 2020). The current study aimed to investigate whether such attention manipulation can also influence healthy decision-making. First, we created a new stimulus set (the NUPF database), including images of natural (healthy) and ultra-processed (unhealthy) food items, for which we obtained ratings on seven scales, including motivational and affective measures. Second, in an online experiment, we manipulated attention by using cues that were presented before two food options were shown. The cues were either directional (left or rightwards pointing) arrows, or neutral (pointing to both the left and right side), and in contrast to the previous study, the food items could either be healthy (unprocessed) or unhealthy (ultra-processed). The directional cues were expected to work as a nudge, biasing attention and choices towards the cued rather than uncued items.

Replicating our previous study, our main analyses showed that even though the cues were task-irrelevant, the directional cues effectively affected attention (Posner, 1980): Participants were faster in choosing a cued versus an uncued, or neutrally cued item. Notably, the effects of the task-irrelevant cues were also reflected in choice behavior. Cued items were chosen more often than neutrally cued and uncued items, for both healthy and unhealthy choices. These findings suggest that our task-irrelevant cues were effective in directing attention and influenced choice behavior as a result (similar to the findings in Vriens, Vidden & Schomaker, 2020). Previously, the use of directional cues such as floor arrows has been shown to be an effective strategy to influence food choices in a grocery store setting: Green arrows, pointing to the direction of the fresh food section, led to increases in the sales of fruits and vegetables (Payne, Niculescu, Just, & Kelly, 2016). Other work has suggested that other environmental factors can influence people's eating behavior: Posters, placed near vending machines primed consumers to buy healthy or unhealthy snacks depending on their content (Stöckli, Stämpfli, Messner, & Brunner, 2016), and exposure to fruity odors nudged people to choose fruit and vegetable options from a menu (Gaillet, Sulmont-Rossé, Issanchou, Chabanet, & Chambaron, 2013). Also, relocating healthy snacks to a visible place by the cash register increased sales of these products (Kroese, Marchiori, & de Ridder, 2015). Prior research has thus shown that there are several ways to influence food choices by nudges; factors that affect someones behavior in a predictable manner, but do not forbid any choices or alter economic incentives significantly (Thaler & Sunstein, 2009). Taken together, our results suggest that an attentional mechanism may underlie the effects of external cues (like arrows) in previous studies and the current study.

Table 3
Model 2: GLMM results for a model predicting response time during the choice phase for healthy-unhealthy trials. Value, calorie density, and portion calories relate to the chosen item, while hunger and happiness were subjective ratings. The b value reflects the regressors' slope (i.e., beta). For this model, we performed a Box-Cox transformation to correct for a violation of homoscedasticity.

		b-value	SE	*t*-value	*p*-value
Degrees of freedom	*254*				
Intercept		**162.35**	**9.17**	**17.69**	**< 0.001**
Value		−0.97	0.54	−1.82	0.071
Calorie density		**0.01**	**0.01**	**2.02**	**0.045**
Portion calories		**−0.07**	**0.02**	**−3.42**	**< 0.001**
Hunger		**−5.82**	**1.10**	**−5.29**	**< 0.001**
Happiness		**−8.04**	**1.20**	**−6.68**	**< 0.001**

We further investigated potential factors that could underlie healthy decision-making in our study by using regression models. We observed that both hunger and happiness decreased the chances that a healthy item was chosen (model 1). In addition, model 2 showed that higher caloric value per portion and higher levels of hunger and happiness were associated with faster responses, while calorie density slowed down responses. These results will now be discussed in more detail.

Results from the current study showed that hungrier participants were more inclined to choose an unhealthy rather than a healthy food item (model 1). Hunger affecting attention and influencing food-related decision-making is in line with the findings of Cheung et al. (2017). They investigated whether hungry participants could be nudged towards healthier food choices: They asked satiated and hungry participants in a cafeteria to make choices between pairs of healthy and unhealthy foods shown in a menu, while pie charts were shown next to the food pairs. The charts suggested that the majority of previous participants made healthy choices. Hungry participants in a control condition, who were not shown pie charts, made fewer healthy choices than satiated participants. In contrast, hungry participants exposed to the pie charts chose as many healthy foods as satiated participants. Based on these findings, it was inferred that hungry participants were in a state of automatic and fast System I processing and when presented with a choice between two food items, heuristics aided them to solve a self-control conflict by promoting healthy choices. Similarly, in our task hunger may have reduced healthy choices by speeding up response times (model 2).

Our finding of model 2 that increased hunger was associated with shorter response times, suggests that hunger led to a stronger attentional focus (see for example Vriens, et al., 2020). This finding is consistent with previous research demonstrating that hungry people show an attentional bias towards food-related stimuli. For example, a dot-probe task showed that hunger biased selective attention towards food-related stimuli (Mogg et al., 1998). Unlike satiated participants, participants who fasted before the experiment shifted their attention more frequently towards food-related words than transport-related control words when these words were presented in pairs. Moreover, Loeber et al. (2013) investigated attention and hunger in a go/no-go task by asking healthy-weight participants to react to target words in go-trials and to inhibit their responses to distractor words in no-go trials. The words were either clothing- or food-related, and it was found that hunger was associated with impaired response inhibition when food-related words were used as distractors in the go/no-go task. Thus, it was inferred that when food-related cues are present, hunger induces approach bias and impairs response inhibition, which might explain why hungry participants in the current study had shorter response times to food stimuli than satiated participants. Moreover, the effect of hunger on attention was demonstrated in an event-related brain potential study showing that hunger affects the processing of food cues in the brain: Stockburger et al. (2009) showed participants food and flower pictures and their ERP recordings suggested that hunger increased attention for food-related stimuli in a processing state associated with stimulus recognition and focused attention, providing physiological evidence for the relationship between hunger and attention. Alternatively, hunger may have influenced approach motivation, resulting in hungry participants responding faster (Robinson, Meier, Tamir, Wilkowski, & Ode, 2009).

Model 1 suggested that happiness increased the chances that an unhealthy food item was chosen, while model 2 suggested that happiness sped up response times. These findings are in line with previous research showing that happier participants reported feeling more positive emotions when looking at food pictures than less happy participants (Otake & Kato, 2016). This response might mirror the anticipatory positive affect happy people would experience when eating these foods. Thus, it is possible that response times observed in the current study reflected differences in the anticipatory positive affect related to eating; happy participants believed that they would enjoy (unhealthy) food more. However, it might also be that happiness sped up response times because this mood is associated with faster response times in general (Schomaker, Rangel-Gomez, & Meeter, 2015). Studer and Winkelmann (2014), for example, asked people how happy they are with their lives, and found an association between slow responses and low levels of happiness. They suggested that those in a good mood responded faster because their answers were more likely to be intuitive and spontaneous. Similarly, it is possible that with increasing happiness, participants in the current study made more intuitive choices between food items, and consequently, had shorter response times.

Interestingly, participants responded faster on trials with two healthy rather than two unhealthy items, and more often chose healthy than unhealthy items. These findings could potentially be explained via the effects of healthiness on attention. Our model 2 suggested that higher calorie density was associated with slower response times, however, higher portion calories was associated with faster response times too. Drift-diffusion models have been successful at explaining decision-making behavior and response times in simple tasks, including binary and trinary choices (Krajbich & Rangel, 2011). The idea behind these models is that information about options is accumulated over time. Once the evidence to favor one option exceeds a certain threshold, a decision is made. The threshold may be dynamically adapted to fit ongoing goals, and optimize the cost of accumulating more evidence against the cost of the time required to come to a decision (Ratcliff, 1978; Bogacz, Brown, Moehlis, Holmes, & Cohen, 2006). A possible explanation is that the healthy items were more easily recognizable than the unhealthy items due to their unprocessed nature, requiring less evidence accumulation than for unhealthy items, which may have been harder to recognize. Findings from the separate rating experiment suggested that healthy items were rated as more desirable, approachable, positive, arousing, recognizable and popular than unhealthy items. Especially the differences in terms of emotional valence or arousal may have sped up response times for the healthy rather than unhealthy items. Also, ease of recognizability or popularity (how often they are consumed) may have sped up response times for the healthy compared to the unhealthy items. This aspect may have been exacerbated by the international background of our participants. Although we showed a menu with food labels in advance of the task, especially some of the processed, unhealthy food items may have been harder to recognize than the more natural-looking healthy items, which may, in turn, have slowed evidence accumulation and decision-making processes for the first compared to the latter. Follow-up tests including only well-recognized items (Recognizability > 5 on a 7-point scale), suggested that healthiness and cue interacted, however, post-hoc tests failed to identify differences in response times for healthy and unhealthy choices for the different cue types. Motivational factors (here measured by approachability and desirability) could potentially also have played a role (Schomaker, Rau, Einhauser, Wittmann, 2017; Schomaker, Walper, Wittmann, Einhauser, 2017).

One limitation of the current study is that participants were making choices between pictures of food items, rather than making choices with real implications. Some studies have suggested that hypothetical choices match real-life choices (Kühlberger, Schulte-Mecklenbeck & Perner, 2002) and effects of attention can be observed in in-store decisions (Clement, Aastrup & Forsberg, 2014), but future studies investigating the effects of top-down attention on food choices could be done in more naturalistic situations, for example involving real food choices, to confirm the generalizability of our findings. Another limitation is that we did not check whether participants were aware of the purpose of the study, that is whether they were consciously using the cues to direct their attention in a top-down fashion or whether their attention was directed in a more reflexive fashion. Previous work has suggested overly learned cues, like the arrows used in the present study, can lead to automatic reorienting of attention (Hommel, Pratt, Colzato, & Godijn, 2001; Tipples, 2002). Differences in beliefs about the cues or cue-related strategies could potentially have affected participants behavior on the task. However, in a previous study we specifically manipulated the instructions regarding the cues (Vriens, Vidden, & Schomaker, 2020). We used the same food-choice task with arrow cues but had three conditions including different instructions: (1) cue-relevant: in which participants were told to use the cues; (2) cue-irrelevant: in which participants were told to ignore the cues; (3) control: in which participants did not receive instructions regarding the cues. We found similar effects of the cues on attention and choice behavior in all three conditions, suggesting that the effects of attention on the cue happen more or less automatic, and participants' beliefs regarding the cues may have had only minimal effects on our measures of interest. The results in the current study could thus be caused by automatic or more voluntary attentional orienting to the cued locations.

6. Conclusion

Previous studies have already shown that stimulus-driven attention (Markowitz, Shewcraft, Wong, & Pesaran, 2011; Milosavljevic et al., 2012; Towal et al., 2013) and viewing behavior (Krajbich & Rangel, 2011; Krajbich et al., 2010) can bias choice behavior, while fewer studies investigated the effects of *attention-directing* cues in decision-making. Our findings suggest that task-irrelevant cues can successfully affect attention and influence choices between food items accordingly. Interestingly, effects of attention were observed for both healthy and unhealthy choices, suggesting that directional cues could potentially be used to promote healthy decision-making in more realistic settings, something that could potentially be used by policy makers to promote healthy decision-making and to curb the obesity epidemic.

CRediT authorship contribution statement

J. Schomaker: Conceptualization, Data curation, Methodology, Project administration, Software, Formal analysis, Writing - original draft, Visualization, Funding acquisition, Supervision. **M. Vriens:** Project administration, Writing - original draft. **HA. Jarva:** Resources, Validation, Writing - review & editing.

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Author contributions

J.S. conceived, designed, and programmed the experiments and used the analyses. M.V. & H.A.J. contributed to the design of the experiment. J.S., M.V. and H.A.J contributed to the writing of the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2021.104384.

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