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4 **Giving Pork the Chop: Response Inhibition training to Reduce Meat Intake**

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13 Declarations of interest: none

14 This research did not receive any specific grant from funding agencies in the public,
15 commercial, or not-for-profit sectors

Abstract

Meat consumption is damaging to the environment, health and animal welfare. Despite a growing interest in reducing meat intake, many people eat too much. This is partly due to the pleasure associated with eating meat. Research has used go/no-go response inhibition training (RIT)¹ to reduce the intake and reward value (liking) of snack foods. However, RIT has not yet been applied to meat. We investigated whether an internet-delivered RIT with meat pictures would reduce meat intake and liking relative to a non-food control RIT condition. Participants (N=81) were meat eaters with a desire to reduce their intake. They completed four 10-minute training sessions in one week. Active participants inhibited responses to meat, and responded to fruits and vegetables. Meat intake was measured using food frequency questionnaires at pre- and one month post-training, and a daily meat diary for one week during training. Liking of meat and other foods was measured at pre- and one month post-training. There was a reduction in meat intake over one month in both groups, with active participants showing a significantly larger decrease than controls. Conditions did not differ in meat intake during the training week. Both groups showed a devaluation of meat, with active participants showing a significantly larger devaluation of food overall, suggesting some generalisation of devaluation effects. The reduced frequency of meat intake was associated with greater devaluation of meat in active but not control participants. These findings suggest that meat RIT helps to reduce meat intake and food liking. Future research should conduct larger randomised controlled trials with longer-term outcomes.

Keywords: Meat, Response inhibition, Cognitive training, Food intake, Food liking, Devaluation.

¹ Abbreviation: Response inhibition training (RIT)

Introduction

Meat production is detrimental to the environment (Garnett, 2008), human health (Tilman & Clark, 2014) and animal welfare (Marie, 2006). Meat and other animal products are responsible for ~14.5% of global anthropogenic greenhouse gas emissions (Springmann et al., 2018; Stoll-Kleemann & Schmidt, 2017). The most detrimental of these are carbon dioxide, methane and nitric oxide, which are commonly produced through pasturing land (Dalal, Wang, Robertson & Parton, 2003), deforestation (McAlpine, Etter, Fearnside, Seabrook & Laurance, 2009) and digestive processes from livestock (Steinfeld et al., 2006). These GHG emissions contribute to global warming (Lashof & Ahuja, 1990), the acidification of oceans (Bernstein, 2008) and air pollution, which is harmful to both humans and the environment (UNEP, 2011).

Meat consumption also has detrimental effects on human health (Tilman & Clark, 2014). Whilst there are many nutrients found in meat (Biesalski, 2005), it (especially red meat) is also high in both saturated fat and cholesterol (NHS, 2015). An excessive consumption of meat, seen in many developed and transition countries (Allieveli, Vinnari, & Luukkanen, 2015), puts individuals at a higher risk of developing non-communicable diseases including coronary heart disease, stroke, type 2 diabetes and cancer (WHO & Consultation, 1990; Wolk, 2017). A meta-analysis suggested that switching to meat-free diets in several developed countries would reduce cardiovascular disease mortality by 29% and reduce overall cancer incidence by 18% (Huang, Yang, Zheng, Li, Wahlqvist & Li, 2012). The broader health, environmental and economic benefits of reducing meat consumption and switching to a more plant-based diet are considerable, with estimates of 12-22% reductions in global mortality, 54-87% reductions in greenhouse gas emissions and economic savings equivalent to 0.4-13% of global gross domestic product (Springmann, Godfray, Rayner & Scarborough, 2016; Springmann et al., 2018). As a result, people in many high- and middle-income countries are being urged to eat 50- 90% less meat (Springmann et al., 2018; Willett et al., 2019).

Due to growing awareness of the above issues, increasing numbers of people in developed countries have reduced their meat intake in recent years (Bates et al., 2014; Neff et al., 2018; Stoll-Kleemann & Schmidt, 2017). For example, a third of adults in the UK reported having reduced their meat intake in 2014 (Lee & Simpson, 2016). However, the drive to consume meat can be strong (Herzog, 2011). It is influenced by many factors including habits, social norms, culture, gender, and political and economic factors (Stoll-Kleemann &

Schmidt, 2017). An important motivating factor is also the pleasant taste (hedonic effects) of meat (Goodson et al., 2002; Verbeke & Vackier, 2004). The enjoyment people derive from eating meat is one of the main justifications they give for eating it, and one of the biggest barriers to reducing intake (Kenyon & Barker, 1998; Lea & Worsley, 2001, 2003; Piazza et al., 2015). The rewarding effects of meat may make it difficult for people to reduce their intake even when they intend to do so (Loy, Wieber, Gollwitzer & Oettingen, 2016; Stubbs, Scott & Duarte, 2018).

A key research goal is therefore to identify interventions that support individuals in reducing their intake of liked but less-healthy foods. Research to date has focused on decreasing the intake of foods high in fat, sugar and salt (HFSS), but there is growing interest in adapting these strategies for meat reduction. For example, Loy et al. (2016) showed that an intervention that enhances self-regulation and reduces unhealthy snacking (implementation intentions; creating “if-then” plans) is also effective when applied to reducing meat intake. Whilst changing people’s meat intake is complex, with interventions suggested at multiple levels of the food system (Bianchi, Dorsel, Garnett, Aveyard & Jebb, 2018; Stoll-Kleeman & Schmidt, 2017; Stubbs et al., 2018), our focus is on interventions aimed at the individual and, in particular, those designed to reduce reward-driven food intake.

Food reward value, as measured by subjective evaluations of food liking and desire to eat, can be decreased using computerized manipulations of affective or motor responses to images of food. One manipulation of affective response is evaluative conditioning (De Houwer, Thomas & Baeyens, 2001), where images of HFSS foods or meat are presented alongside images of aversive ‘outcomes’, such as disease or vomit (e.g. Hollands, Prestwich & Marteau, 2011; Tybur, Laakasuo, Ruff & Klauke, 2016). Evaluative conditioning is effective in decreasing implicit or explicit evaluations of food, but its effects on eating behavior (i.e. reducing food intake or choice) are unclear (e.g. Hensels & Baines, 2016; Hollands et al. 2011; Lebens et al., 2011; Walsh & Kiviniemi, 2014). Evaluative conditioning also involves repeated viewing of aversive images, which may reduce its acceptability as a meat-reduction intervention. In contrast, changing the motor response to food images, through food-associated response inhibition training (RIT), has shown robust effects on reducing food reward value and food intake (Stice, Lawrence, Kemps & Velting, 2016; Velting, Lawrence, Chen, van Koningsbruggen & Holland, 2017). It is also simple to complete and highly acceptable to users (Lawrence et al., 2015a).

Food RIT requires people to inhibit responding to certain foods presented during computerized go/no-go or stop-signal tasks. People are asked to press a button when a go cue is presented alongside an image and to refrain from pressing a button when a no-go cue (e.g. a bold frame) is presented. Importantly, some food images (e.g. HFSS items) are consistently presented with no-go cues, and other food images (e.g. vegetables) or non-food images are consistently presented with go cues. The training creates an association between specific foods, or categories of food, and the inhibition of a motor response (Serfas, Florack, Büttner & Voegeding, 2017; Veling et al., 2017). Across many studies this training has been shown to reduce the intake and choice of trained ‘no-go’ HFSS foods (Adams, Lawrence, Verbruggen & Chambers, 2017; Folkvord, Veling & Hoeken, 2016; Houben, 2011; Houben & Jansen, 2011; 2015; Lawrence et al., 2015a; 2015b; Oomen, Grol, Spronk, Booth & Fox, 2018; Porter et al., 2018; van Koningsbruggen, Veling, Stroebe & Aarts, 2014; Veling, Aarts & Papies, 2011; Veling, Aarts & Stroebe, 2013a, 2013b). Meta-analyses suggest that food no-go (vs. control) training has moderate effect sizes on reducing immediate HFSS food intake (Cohen’s $d = 0.5$; Allom, Mullan & Hagger, 2016; Jones et al., 2016; Turton, Bruidegom, Cardi, Hirsch & Treasure, 2016).

Numerous studies also show that no-go foods, relative to untrained or go foods, show a reduction in subjective ratings of food liking or attractiveness from pre- to post-training (Chen, Veling, Dijksterhuis & Holland, 2016; Chen, Veling, Dijksterhuis & Holland, 2018a; Chen et al., 2018b; Lawrence et al., 2015a; Serfas et al., 2017; Veling et al., 2013a). This devaluation may result from a conflict between the trained ‘no-go’ response and the pre-existing automatic approach tendency leading to negative affect becoming associated with ‘no-go’ foods (Chen et al., 2016; 2018a, 2018b; Chiu, Cools & Aron, 2014). Devaluation may also result from a reduced motivational/incentive value for ‘no-go’ foods (Berridge, Ho, Richard, & DiFeliceantonio, 2010), because these have been associated with decreased motor cortex excitability, response effort, and response speed (Freeman, Razhas & Aron, 2014; Houben & Giesen, 2018; van de Vijver, van Schie, Veling, van Dooren, & Holland, 2018; Van Koningsbruggen, Veling, Stroebe & Aarts, 2014; Verbruggen & Logan, 2008).

It is unclear what mechanism(s) drive the reduced food intake and choice seen with food RIT because very few studies have systematically examined this. Some evidence points to a role for food devaluation mediating training effects on choice (Veling et al., 2013a) and correlating with weight loss effects (Lawrence et al., 2015a). It is also possible that the training strengthens top-down inhibitory control towards ‘no-go’ foods, or creates automatic

‘bottom-up’ associations between ‘no-go’ foods and stopping responses (Best, Lawrence, Logan, McLaren, & Verbruggen, 2016; Stice et al., 2016; Veling et al., 2017). These proposed mechanisms are not mutually exclusive and may interact, e.g. with response conflict leading to devaluation early on during training, followed by the development of ‘automatic’ inhibition with more training (see Veling et al., 2017 for discussion). We chose to measure devaluation rather than other potential mechanisms of RIT (such as improvements in inhibitory control) in this study. This was for a number of reasons: i) Devaluation was more closely related to the process we were trying to change (meat liking, which is a common barrier to reducing meat intake); ii) devaluation is relatively quick and simple to measure and we were keen to reduce participant burden in this online experiment; iii) there is robust evidence supporting devaluation of food following RIT (at least 15 published experiments: Chen, Veling, Dijksterhuis & Holland, 2016; Chen, Veling, Dijksterhuis & Holland, 2018a; Chen et al., 2018b; Lawrence et al., 2015a; Serfas et al., 2017; Veling et al., 2013a). In contrast there is limited evidence that RIT strengthens inhibitory control: Whilst several studies have shown better performance on RIT training tasks over time (e.g. Lawrence et al., 2015a, 2015b, Stice et al., 2017; Forman et al., 2019), none have shown improved inhibitory control to food or alcohol on a separate task (Houben, Havermans, Nederkoorn, & Jansen, 2012; Jones et al., 2018; Oomen et al., 2018; Poppelaars et al., 2018).

Whilst the precise mechanism(s) behind RIT remains unclear, training effects appear to be relatively automatic: They are independent of people’s explicit intentions to diet (Veling et al., 2014) and of their awareness of the aims or contingencies of the training (Lawrence et al., 2015a; 2015b). Indeed, most of the above studies were conducted in healthy young adults who were naïve to the aims of the training, although real-world trials have recruited targeted groups of individuals who were trying to lose weight or eat more healthily (Forman et al., 2019; Lawrence et al., 2015a; Veling, van Koningsbruggen, Aarts & Stroebe, 2014). The ‘automatic’ nature of RIT effects stands in contrast to other interventions that target ‘conscious determinants’ of behavior, such as self-monitoring (Bianchi et al., 2018a) and implementation intentions, where effects are moderated by the strength of people’s explicit intentions (e.g. to reduce their meat intake; Loy et al., 2016). Whilst food RIT could potentially affect anyone, regardless of their intention to change, it is obviously more ethical and acceptable to offer it to those who want to change. Therefore, this study examined the effects of meat no-go training in people who had a desire to reduce their meat intake.

Studies to date have mainly trained inhibitory responses to HFSS foods (mostly snacks like chocolate or crisps) within the context of healthier eating and weight loss. However, there is considerable evidence that RIT can be successfully applied to other types of stimuli. It has been shown to reduce the consumption and reward value of alcohol (see Jones et al., 2016 for a meta-analysis), cigarettes (Scholten, Granic, Chen, Veling & Luijten, 2019), faces and bodies (Doallo et al., 2011; Ferrey, Frischen & Fenske, 2012), positive images (cute animals, flowers; Veling, Holland, & van Knippenberg, 2008) and abstract shapes (Wessel, O'Doherty, Berkebile, Linderman & Aron, 2014). However, no one has yet examined whether RIT can be specifically applied to meat to help people reduce their consumption. Therefore, we compared meat intake and liking in two groups of participants before and after they completed four days of either active (meat-related) or control (non-food related) RIT. We predicted that participants in the active condition would show greater reductions in meat intake and liking than those in the control condition. Active participants inhibited responses to meat, and executed 'go' responses to fruits, vegetables and non-food filler pictures. Whilst most previous studies have trained 'no-go' responses to food vs. 'go' responses to non-food items (Houben & Jansen, 2011; 2015, Van Koningsbruggen et al., 2014; Veling et al. 2013a; 2013b; Veling, van Koningsbruggen, Aarts & Stroebe, 2014), we replicated our previous approach of training 'go' responses to fruits and vegetables (Adams et al., 2017; Lawrence et al., 2015a). We did this because it is important that people replace meat products in their diets with fruits and vegetables for maximum health benefits (Springmann et al., 2018). In addition, recent evidence suggests that larger and more sustained no-go devaluation effects are seen when go and no-go responses are trained to 'meaningful' categories, such as healthy and unhealthy foods (Serfas et al., 2017).

Material and Methods

Participants and design

Participants were assigned to either the active (meat stimuli) or the control (non-food stimuli) condition via alternate allocation. The dependent variables were food ratings and meat intake before and after training. Inclusion criteria required that participants were aged 18-65 years, that they ate meat and had some desire to reduce their meat intake. Participants were recruited from the University of Exeter and wider community using advertisements displayed around campus, on university websites and disseminated via social media by a

relevant external organisation (Meat Free Mondays). Student participants were also recruited using the University of Exeter's online experiment management system in exchange for course credits. Other participants did not receive any compensation. Study advertisements asked for participants who wanted to reduce their meat intake and highlighted some of the reasons for eating less meat in an infographic. Participants were informed that they would be assigned to an active or control group and that the intervention may or may not help them to reduce their meat intake. They gave informed consent via an online survey. The study was approved by the University of Exeter's school of Psychology Research Ethics Committee.

Power calculation

An a-priori power calculation using G*Power 3.1.9.2 (Faul, Erdfelder, Lang, & Buchner, 2007) indicated that 40 participants would be required to detect a medium effect size for the interaction between time and group ($f=0.25$) with 95% power and an alpha level of 0.05. This estimate was based on the time x group interaction effects for weight-loss ($f=0.29$) and reduced energy intake ($f=0.25$) in our previous trial of food ICT (Lawrence et al., 2015a). We planned to recruit and randomise 80 participants to allow for exclusion and attrition because our exclusively online studies have higher attrition rates (~50%) than our combined face-to-face + online studies (e.g. 3% in Lawrence et al., 2015a). This target was exceeded with 106 participants being randomised. However, after exclusions and attrition, our final sample consisted of 81 participants (see Figure 1 for recruitment flow chart). Reasons for exclusion included poor performance on the training task (more than three *SDs* below the group mean, $n = 7$). Six of these seven excluded participants had less than 10% accuracy on no-go trials and one had less than 50% accuracy on go trials, suggesting they had not understood the task instructions.

Figure 1. Recruitment flow diagram. This shows the number of participants included in each condition at each stage of the study.

Training task

The online training task was the go/no-go training task used in Lawrence et al. (2015a), with the active condition modified to include meat images instead of the energy-dense food images used in Lawrence et al. (2015a). The active training task contained eight meat images (all no-go), eight healthy food images (fruit, vegetables and rice- cakes, all go) and 16 filler

images (clothes) that were 50% go and 50% no-go. The control training task contained 16 household goods (eight tools and stationery, which were no-go; eight furniture, buckets and electrical appliances, which were go) and 16 filler images (clothes), which were associated with 50% go and 50% no-go images. The inclusion of filler images with unpredictable responses served to make the tasks more challenging and engaging, and aimed to make the rules less obvious in order to recruit learning in the automatic, associative system, rather than the explicit, rule-based system.

During the training, single images appeared on either the left or right hand of the screen for 1250 ms within a narrow border (see Figure 2), followed by a 1250 ms inter-stimulus interval. Participants were asked to press the left or right arrow key on the keyboard as quickly and as accurately as possible to indicate on which side of the screen the image appeared. On half of the trials the border of the box was bold (see Figure 2), which indicated that participants should withhold their response (no-go signal). Each training session consisted of six blocks of training, with 32 images presented in a random order per block. Each session took 8-10 minutes to complete. Consistent with our previous RIT trial (Lawrence et al., 2015a), participants were provided with feedback in terms of their percentage accuracy (separately for go and no-go trials) and go reaction times (in ms) at the end of each block, and were encouraged to keep improving their score. Incorrect responses included failing to accurately respond to the go-stimuli or making any responses to the no-go stimuli. Providing participants with feedback is often implemented in RIT tasks (e.g. Forman et al., 2019; Houben & Jansen, 2011; Lawrence et al., 2015a; Veling et al., 2014) as it may help to increase motivation and engagement (e.g. Jones et al., 2018).

Figure 2. Example of the stimuli included in the active (meat) condition ‘go’ and ‘no-go’ trials. All healthy stimuli were presented on the go trials, all the meat stimuli were presented on the no-go trials (bold frame) and the filler (clothes) stimuli were presented on both the go and no-go trials. Food images are from the FoodPics database (Blechert et al., 2015).

Food stimuli

The non-food images in the control condition and the healthy food (go) images in the active condition were the same as those used previously (see Lawrence et al. 2015a for details). The eight meat (no-go) images in the active condition were selected as follows: First, data from the Departments for Environmental Food and Rural Affairs (DEFRA) were used to identify the eight most popular (purchased and eaten) meats in the UK. These were; beef-burger, bacon, pork chop, chicken breast, ham, minced beef, steak, and sausages. Two exemplars of each of these cooked meat products were chosen from the FoodPics database (Blechert, Meule, Busch, & Ohla, 2015) supplemented with images from google images where necessary. When choosing from the database, we selected the most highly rated (for palatability and craving) relevant meat pictures. The images were cropped and re-sized (280 x 280 cm pixels), leaving simple food items against a white background. Members of the public attending a community event at the University of Exeter (32 adults) were asked to choose which picture of each meat product looked the most palatable. The eight preferred

meat pictures (one of each of the above meat items) were included in our training task. This selection process aimed to ensure that images of palatable and frequently eaten meat were included in our training, as these are the most likely to evoke stronger motor approach impulses, which the no-go training aims to modify (Veling et al., 2017).

Outcome measures

Food frequency questionnaire

Participants were asked to complete a short food frequency questionnaire (FFQ) for the previous month at pre- and post-training. FFQs have been used in previous studies of unhealthy eating behaviour (Churchill and Jessop, 2011) and in real-world trials of food RIT (Lawrence et al., 2015a; Veling et al., 2014). We used a FFQ because it is useful for measuring the intake of specific foods (such as meat products) over longer periods of time (such as one month), and it places a low burden on participants (Thompson et al., 2015). The items in the FFQ were modified from Lawrence et al. (2015a) to fit the needs of the current intervention. Therefore, the meat products from the active training task (seven meats – “sausages” were accidentally omitted) were rated individually, along with an option for “other meats” and “fruits”, “vegetables” and “crispbreads” (“go” food categories in the active training). Participants rated how often the foods were consumed over the previous month using an eight point scale (ranging from 8 = “4 or more times a day”, to 1 = “less often or never” - see open access data file for all response options). A mean FFQ score for meat (based on the average for the seven items from the active training) and healthy food (based on the average for the three ‘go’ categories included in the active training) was calculated for each participant at pre- and post-training.

Daily meat intake diary

Participants were asked to record their daily meat intake during the week they completed the training (starting on their first day of training) by noting this down on a calendar, which was emailed to participants as a word document. The amount eaten on each day was entered as portions of meat according to typical guidelines (with one portion of meat equivalent to the size of a deck of cards, e.g. one chicken breast or two sausages; British Dietetic Association, 2016). This intake diary aimed to provide a more detailed measure of meat intake in each condition. However, in order to simplify procedures and reduce

participant burden, participants were only asked to complete this for one week after commencing training, rather than also during a pre-training week.

Food ratings

A link to a computerised stimulus evaluation test (adapted from Lawrence et al. 2015a) was included in the pre- and post-training questionnaires. Participants were asked to rate how much they liked the taste of 34 different food items, including 16 meat items. Participants moved a cursor along a 100mm visual analogue scale, rating their liking from ‘not at all’ (0mm) to ‘very much’(100mm). They rated eight different healthy foods (fruit, vegetables), which were different exemplars of the 100% go images used in the active training. They also rated 10 energy-dense (‘unhealthy’) foods that did not include any meat and did not appear in the training (e.g. chips, pastries, cheese, ice cream). These untrained unhealthy foods were included to assess the specificity of any change in ratings of go or no-go foods over time. The healthy and untrained food images were retrieved from the FoodPics database (Blechert et al., 2015). The 16 meat images that were rated included the eight 100% no-go images used in the active training task and eight different exemplars of these meat items. Participants were asked to carry out the same stimulus evaluation test before, and one month after their training. A mean liking rating for each food category (healthy, unhealthy and meat) was calculated for each participant at pre- and post-training.

Procedure

The study was conducted entirely online. Whilst most real-world studies of RIT have delivered training online, they have usually involved some face-to-face meetings with researchers to enable certain measures (e.g. weight) to be taken. However, exclusively online RIT has several benefits (e.g. improving participant access and privacy, reducing researcher and participant burden), and it has recently been validated in a trial of alcohol-RIT (Strickland, Hill, Stoops, & Rush, 2019). In our study, participants first contacted the researcher via email. They were sent an email containing all of the information needed to complete the baseline measures and intervention, including website links to the pre-training survey and the training. The link to the training was also provided at the end of the pre-training survey. Participants were given a unique id number that was allocated to the active or control condition and were sent website links appropriate for their condition. Participants were blind to condition allocation. Note that although equal numbers of interested

participants were allocated to the active and control conditions, the number of participants who initiated the study by completing some of the pre-training survey was greater in the active condition (see Figure 1). The daily meat intake calendar with instructions was also attached to the email sent to participants.

Participants accessed the pre-training survey, which provided them with information about the study and obtained their consent. They answered initial questions about their age, sex and whether they wanted to reduce their meat intake (those answering “no” were later excluded). Those who said ‘yes’ were asked whether they had a specific reason for wanting to reduce their meat intake (open response). Participants were also asked to rate how much they “struggle to resist the urge to eat meat” on a scale from 1-9 (from 1 = “not at all” to 9 = “extremely”). Next, participants completed the FFQ, followed by the stimulus evaluation test. At the end of the pre-training survey, all participants were asked to watch a short (2:25 minute) animated film produced by an Australian animal protection organisation (<https://www.youtube.com/watch?v=7I0v3LhKhQg>) explaining the detrimental effects of animal agriculture. This video was included to provide all participants with a basic level of background knowledge and to increase their motivation to complete the study. We also intended that the educational video and self-monitoring of meat intake in both conditions would reduce participants’ awareness of which condition they were in, and reduce demand characteristics. A previous trial of a different meat reduction intervention also used an ‘information-only’ plus self-monitoring condition as a control (Loy et al., 2016).

After completing the pre-training survey, participants were encouraged to complete their first session of RIT. They were asked to complete it four times (on different days) during the week and to complete their daily meat intake calendar for that week. They were encouraged to complete the training alone, in a quiet environment, and ideally before a meal when they might usually eat meat. The online RIT included a clear set of instructions and recorded participants’ id number and task performance. We did not check and encourage compliance (e.g. using reminder phone calls or emails) because we wanted to determine the feasibility of online meat no-go training by measuring natural rates of compliance.

Participants were contacted by email 4 weeks after their first training session and asked to complete the post-training survey. This included the FFQ and stimulus evaluation test, several feedback questions and the study debrief. The feedback questions asked participants a series of funnelled debriefing questions to gauge their ‘awareness’ of the task (stimulus-no-go) associations (as in Lawrence et al., 2015a). Briefly, these questions asked participants if

they had noticed anything in particular about when they had to inhibit pressing a key in the task. Participants were coded as ‘aware’ if they correctly reported that some specific stimuli or categories of stimuli (e.g. “meat”, or “tools” in the control task) were associated with a no-go response. If they failed to provide any comment or simply reported the task instructions (i.e. that they had to inhibit responding when the image border was bold) they were coded as ‘unaware’. In order to gather feedback about the training, participants were asked whether they thought the training had helped them to reduce their meat intake and whether they would recommend it to a friend who was trying to reduce their meat intake; possible responses were “yes”, “no” or “not sure”. They were also asked for any other comments, in particular about how the training had affected them and whether they had any suggestions for improving it, such as whether more personally relevant meat pictures should be used.

Statistical analyses

Mixed effects ANOVAs were conducted on the main dependent variables (meat intake and food liking) using SPSS 25 (IBM Corp, 2017). We predicted significant interactions between group and the repeated measures (time, food category), with greater decreases in the active than control group. Daily meat intake was assessed during the week of training only, so this was compared between groups using one-way ANOVA. Groups were also compared for baseline variables, training task performance and post-training awareness and feedback using one-way ANOVAs or chi-squared tests for categorical variables, with $\alpha = .05$ for all analyses. Additional exploratory analyses examined correlations between outcome measures, and compared sub-groups based on awareness of the training task contingencies. Data files are deposited in the University of Exeter's Open Research Exeter repository under the following identifier: (https://www.dropbox.com/s/q9ii0nisv3d3ikf/Raw_Data_ORE.xlsx?dl=0; https://www.dropbox.com/s/65lg20550ueyr5p/Meat_Data_ORE.sav?dl=0).²

Results

All 81 eligible participants from whom baseline and at least some post-intervention measures were available were included in analyses. Randomization checks showed the groups were generally well matched for baseline factors and the amount and accuracy of

² The link for Exeter's Open Research repository will be provided after peer review. These links are for the data in a public dropbox folder (data in Excel and in SPSS).

training completed (see Table 1). However, the active group reported slightly higher ratings for how much they struggled to resist meat, and the control group were faster to respond on go trials in the training task.

We asked participants whether they had a specific reason for wanting to reduce their meat intake. Those who did give a reason ($n=49$, 61% of the sample) cited health reasons ($n=19$, 39%), moral reasons such as animal welfare and/or environmental concerns ($n=19$, 39%), or a combination of health and moral reasons ($N=11$, 22%). These reasons for reducing meat intake showed a similar distribution across the active and control groups ($\chi^2(2,49) = 5.5, p = .07$).

Variable	Control (n=33)	Active (n=48)	F value ^a (p)
Age	25.03 (10.63)	24.1 (10.33)	0.15 (.7)
Sex (% female)	82%	85%	0.19 (.67)
Pre-training meat intake (FFQ)	2.38 (0.69)	2.45 (0.6)	0.25 (.62)
Pre-training healthy food intake (FFQ)	4.84 (1.16)	4.83 (1.01)	0 (.98)
Pre-training meat liking	62.37 (12.51) ¹	66.26 (12.53) ²	1.8 (.19)
Pre-training healthy food liking	65.38 (13.59) ¹	66.39 (13.17) ²	0.1 (.75)
Pre-training unhealthy liking	65.56 (13.21) ¹	69.32 (13.66) ²	1.41 (.24)
Resist meat	4.61 (1.98)	5.56 (1.89)	4.81 (.03)
Training sessions	3.33 (1.31)	3.38 (1.08)	0.02 (.88)
Go Accuracy (%)	94.95 (7.85)	96.46 (5.43)	1.05 (.31)
No-go Accuracy (%)	87.5 (12.25)	91.45 (7.81)	3.22 (.08)
Go RT (ms)	495.86 (57.56)	544.72 (70.35)	10.89 (.001)

Table 1. Summary of demographics, baseline food intake, liking and Go/No-Go training performance in the active and control group. Note. Standard deviations are presented between the parentheses. FFQ = Food Frequency Questionnaire score out of 8, “Resist meat” refers to how much participants struggle to resist the urge to eat meat out of 9. ¹Missing data from one participant in this group. ²Missing data from six participants in this group.

Training Task performance

Overall accuracy for the go ($M=95.9\%$, $SD = 6.52$) and no-go ($M=89.8\%$, $SD = 10$) trials was high. The active group demonstrated slightly higher no-go accuracy and slower go RT than the control group (Table 1), suggesting a speed-accuracy trade-off. Both groups completed a similar amount of training, with over half of participants (56.79%) completing four training sessions as instructed. The remaining participants completed three sessions

(21%), two sessions (12.35%) or one session (9.9%; see Figure 1 for breakdown per training condition). All participants who completed at least one session of training were included in the analysis (as in Lawrence et al., 2015a).

For two-thirds of our sample ($n=53$) we collected sufficiently detailed training task data to compare responses to 100% ‘predictive’ images (i.e. meat or the control task equivalent) vs. the 50% ‘predictive’ filler images to examine stimulus-response learning during training³. We expected to see improved no-go performance and faster go RT for the 100% vs. 50% predictive images (as in Lawrence et al., 2015a). We compared responses to predictive vs. filler images averaged over all of each participants’ training sessions in two 2 (image type) x 2 (condition) ANOVAs. For no-go accuracy, there was a main effect of image type ($F(1,51) = 8.49, p = .005, \eta^2 p = .14$), with higher no-go accuracy for the 100% no-go stimuli ($M=88.5, SD = 10.92$) than the filler images ($M=86.7, SD= 10.92, 95\% \text{ CI for difference} = .006-.032$). There was no main effect of, or interaction with, condition (p ’s > 0.27). For go RT, there was a main effect of image type ($F(1,51) = 46.75, p < .001, \eta^2 p = .48$) with faster responding to the 100% go stimuli (healthy food or control equivalents; $M=509.3, SD = 64.5$) than the 50% go filler images ($M=526.95, SD = 69.09; 95\% \text{ CI for difference} = -22.83 - -12.47$). There was no main effect, or interaction with, condition in this sub-sample of 53 participants (p ’s > 0.07). These findings suggest that stimulus-response learning occurred as expected in both groups (as in Lawrence et al., 2015a; Stice, Yokum, Veling, Kemps & Lawrence, 2017).

Meat Intake

Both groups showed a reduction in meat intake (one month FFQ scores) from pre- to post-training and this was larger in the active than control group (Figure 3). Complete FFQ data were available from 75 participants (43 active, 32 control). A 2 (time) x 2 (condition) ANOVA showed the expected interaction between time x condition ($F(1,73) = 5.96, p = .017, \eta^2 p = .08$). Simple contrasts showed that meat intake decreased over time in both the active ($M= -0.52, SD = 0.65, p < .001, \text{Cohen’s } d_z = -0.92$) and control ($M= -0.24, SD = 0.75, p = .02, \text{Cohen’s } d_z = -0.63$) groups. However, the change was significantly greater in the active than control group ($U = 469, z = -2.36, p = .018, r = -0.27$), with a medium effect size ($f=0.29; \text{Cohen’s } d = 0.6$). Furthermore, whilst there was no difference between groups for

³ For the first 28 participants the response files did not record which image was shown on each trial so we could only calculate overall go RT and no-go accuracy, rather than responses to each category of images.

meat intake before training (see Table 1), there was a difference at post-training, when controlling for pre-training intake ($F(1,72) = 7.56, p = .008, \eta^2p = .1$). The main ANOVA showed no overall difference between conditions ($F(1,73) = 0.25, p = .62, \eta^2p = .003$) but there was a highly significant effect of time ($F(1,73) = 42.82, p < .001, \eta^2p = .37$), with reductions in meat intake from pre ($M = 2.34, SD = 0.61$) to post-training ($M = 2, SD = 0.46$; 95% CI for difference = -0.49 - -0.26).

Figure 3. Change in meat intake from pre- to post-training. Error bars denote the within-subjects standard error of the mean (SEM).

A 2 x 2 ANOVA on healthy food intake⁴ did not show any significant effects of group or interactions (both $p > 0.7$). There was a small effect of time, with increases in healthy food

⁴ Separate 2 x 2 ANOVAs were conducted on FFQ scores for meat and healthy food intake because their units of measurement were not directly comparable: Participants rated their frequency of intake for single meat items (e.g. “beef-burger”) for meat intake but they rated their intake of broad categories (e.g. “fruit”) for healthy food.

intake from pre ($M = 4.89$, $SD = 1.07$) to post-training ($M = 5.12$, $SD = 1.16$; $F(1,73) = 4.52$, $p = 0.04$, $\eta^2p = .058$, Cohen's $d_z = 0.23$, 95% CI for difference = 0.014 - 0.45).

We also measured meat intake during the intervention week using a daily meat diary. Data for the 7 days from the first training session were available for 57 participants (32 active, 25 control). Of the 24 participants with missing data, 15 had returned a meat diary covering the incorrect week and 9 failed to return a diary. A one-way ANOVA showed that contrary to our prediction, the total number of portions of meat eaten was similar in the active ($M = 8.33$, $SD = 3.85$) and control group ($M = 7.8$, $SD = 4.1$; $F(1,56) = .25$, $p = .62$, $\eta^2p = .005$).

Changes in meat evaluation

Participants rated their liking for three different categories of food images (meat, healthy foods and untrained unhealthy foods) at pre- and post-training. As shown in Figure 4, the greatest reduction in liking (devaluation) was seen for meat (black lines), with a smaller reduction in liking for unhealthy food (mid-grey lines) and no change for healthy food (light-grey lines). Complete liking data were available from 67 participants (37 active, 30 control).

A 3 (food-type: meat, healthy, unhealthy) x 2 (time) x 2 (condition) ANOVA showed no three-way interaction between time x food-type x condition (Greenhouse-Geisser corrected $F(1.45, 94.02) = 0.54$, $p = 0.53$, $\eta^2p = 0.008$). However there was a significant time x condition interaction ($F(1,65) = 4.61$, $p = .035$, $\eta^2p = .07$, Cohen's $d = 0.53$). Simple contrasts showed significant reductions in food liking over time in the active group ($M = -4.93$, $SD = 6.39$; $F(1,65) = 22.05$, $p < .001$, $\eta^2p = .25$, 95% CI for difference = -7.03 - -2.83) but not in the control group (overall $M = -1.56$, $SD = 6.41$; $F(1,65) = 1.79$, $p = 0.19$, $\eta^2p = 0.03$, 95% CI for difference = -3.89 - 0.77). There was also a significant time x food-type interaction (Greenhouse-Geisser corrected $F(1.45, 94.02) = 15.24$, $p < .001$, $\eta^2p = .19$). Contrasts showed significant reductions over time for meat liking ($M = -8.4$, $SD = 13.95$; $F(1,65) = 24.58$, $p < .001$, $\eta^2p = .27$, 95% CI for difference = -11.79 - -5.02) and unhealthy food liking ($M = -2.32$, $SD = 8.51$; $F(1,65) = 4.94$, $p = .03$, $\eta^2p = 0.07$, 95% CI for difference = -4.4 - -0.23), but not healthy food liking (overall $M = 0.99$, $SD = 7.61$; $F(1,65) = 1.13$, $p = .29$, $\eta^2p = 0.02$). Pairwise contrasts between food categories showed no differences before training (all p 's > 0.23) but after training, meat was liked significantly less than healthy food ($M = -10.91$, $SD = 21.36$, $p < .001$, 95% CI for difference = -16.13 - -5.69) and unhealthy food

($M = -8.75$, $SD=18$, $p < .001$, 95% CI for difference = $-13.15 - -4.36$). These findings suggest a substantial devaluation of meat over time that showed some generalisation to untrained unhealthy foods. The devaluation of food (in general) was only observed to a significant degree in the active group.

Although the ANOVA did not show the predicted three-way interaction, in order to assist with data interpretation and planning for future studies, we computed effect sizes for the significant food devaluation effects within each condition. The active participants showed a large devaluation of meat from pre- to post-training ($M = -11.12$, $SD = 15.82$, $t(36) = -4.28$, $p < .001$, 95% CI for difference = $-16.4 - -5.85$, Cohen's $d_z = 0.7$) and the controls showed a medium devaluation effect ($M = -5.68$, $SD = 10.77$, $t(29) = -2.89$, $p = .007$, 95% CI for difference = $-9.7 - -1.66$, Cohen's $d_z = 0.53$). The devaluation of untrained food was also significant in the active condition with a medium effect size ($M = -3.51$, $SD = 6.73$, $t(36) = -3.17$, $p = .003$, 95% CI for difference = $-5.76 - -1.27$, Cohen's $d_z = 0.52$). There were no changes in evaluation of untrained food in the control condition ($p=.55$), or of healthy food in the active ($p=0.91$) or control ($p = .08$) condition.

Figure 4. Liking ratings for meat, healthy and untrained unhealthy food. Data shows mean liking (on 100 mm VAS) at pre- and post-training in the active (solid lines) and control (dashed lines) groups. Error bars = within-subjects standard error of the mean (SEM).

Exploratory correlations between devaluation and intake

We examined whether the reduction in meat intake from pre- to post-training (meat change score) was associated with changes in meat liking (meat devaluation) within each group. Change scores (post- minus pre-training) were not normally distributed so we used non-parametric (Spearman's rho) correlations. There was a positive association between changes in meat intake and changes in meat liking in the active condition ($r_s(37) = 0.45, p = .006$), suggesting that participants who showed larger decreases in liking also showed larger decreases in meat intake. Control participants showed no association between changes in meat intake and liking ($r_s(30) = -0.005, p = .98$). The difference between these correlations was borderline-significant ($z=1.9, p = .057$).

Task Awareness

The post-training survey (completed 4 weeks after training) showed a large difference between conditions for ‘awareness’ of stimulus-signal associations in the training task. Around half of the active participants ($n=20$, 48%) correctly reported that the no-go signals had been associated with meat pictures, but no control participants (0%) reported that they had to withhold from specific images such as tools. This difference was highly significant ($\chi^2(1, 74) = 20.88, p < .001$). We compared the ‘aware’ and ‘unaware’ participants in the active condition to see if they showed any differences in outcome measures, i.e. changes in food evaluation and intake (as in Lawrence et al., 2015a). Non-parametric (Mann-Whitney U tests) were used where necessary. The reduction in meat intake in aware participants ($Mdn = -0.43$) did not differ from that in unaware participants ($Mdn = -0.57, U = 228.5, z = 0.22, p = .83, r = 0.03$). However, the reduction in meat liking was larger in aware participants ($Mdn = -10.81$) than in unaware participants ($Mdn = -4, U = 89.5, z = -2.48, p = .012, r = -0.41$). There was also a significantly larger increase in liking of healthy foods in aware ($M = 3.51, SD = 6.97$) than unaware participants ($M = -4.01, SD = 8.23, t(35) = 3, p = .005$). Conversely, the change in liking for untrained unhealthy foods did not differ as a function of awareness (aware $M = -3.21, SD = 7.31$; unaware $M = -3.83, SD = 6.23$; $t(35) = 0.28, p = .79$). These findings suggest that awareness of the meat-no-go associations were related to changes in evaluation of trained foods but not to changes in meat intake.

Task feedback

Participants were asked whether they had found the training helpful and if they would recommend it to a friend who was trying to reduce their meat intake. The majority of participants in the active condition said it was or might have been helpful (69%), and they would or might recommend it to a friend (78.5%). The active group were more positive about the intervention than the control group (see table 2).

Do you think the training helped you to reduce your meat intake?				
	Yes	Not sure	No	χ^2 value (p)
Active	13 (31%)	16 (38%)	13 (31%)	12.04 (.002)
Control	0 (0%)	17 (53.1%)	15 (46.9%)	
Would you recommend this training to a friend who was trying to reduce their meat intake?				
	Yes	Not sure	No	χ^2 value (p)
Active	19 (45.2%)	14 (33.3%)	9 (21.4%)	7.41 (.025)
Control	5 (15.6%)	15 (46.9%)	12 (37.5%)	

Table 2. Acceptability of the no-go training intervention in the active and control group.
Note. Number of participants giving each response given as total number and as a percentage of the respondents in that group.

In terms of open feedback about the effects of the training, several active participants commented that they did not feel like eating meat as much, the idea of eating meat had become unpleasant, or they found themselves “saying ‘no’ in their head” when looking at meat (see open access data file for individual responses). However, some active participants said they did not reduce their meat intake during the training week because of social/environmental factors, such as eating out, at barbecues or already having meat in their fridge. Some participants in both conditions reported that other aspects of the procedure (the educational video, self-monitoring their intake) made them more aware of what they were eating and made them think about having a more balanced diet.

Discussion

There is growing interest in using behaviour change interventions to help people eat less meat (Bianchi et al., 2018a; 2018b; Loy et al., 2016). This study is the first to examine whether response inhibition training (RIT) can help to reduce meat intake in motivated individuals. Participants were asked to complete four go/no-go training tasks during one week whilst recording their meat intake. They were also asked to report their meat intake over the month preceding and the month following training, and to provide subjective ratings

for how much they liked meat. It was hypothesised that those completing the active (meat-associated) RIT would show a greater reduction in both meat intake and liking than those completing the control (non-food) RIT.

In line with this hypothesis, the frequency of meat intake over one month showed a significantly larger decrease from pre- to post-training in the active, compared to the control condition. This is consistent with findings showing larger reductions in energy intake and weight in participants trained to ‘no-go’ to HFSS foods relative to non-foods (Lawrence et al., 2015a; Veling et al., 2014). Performance data from the training tasks (no-go accuracy and go RT) suggested that participants in both groups learned the relevant stimulus-response associations, with active participants learning to inhibit more accurately to the 100% no-go meat pictures than the 50% no-go fillers. This learnt inhibition to meat pictures may have generalised (shown far-transfer effects) and encouraged participants to withhold from meat products in real-life. Indeed, comments from some active participants support this, e.g., “I could feel myself saying “no” in my head when I saw the meat images which reminded me to not go for the meat option in real life”. However, interestingly, and consistent with our previous findings (Lawrence et al., 2015a), reductions in meat intake were seen irrespective of whether or not participants could report the meat-no-go associations in the task.

On the other hand, our second measure of meat intake (daily meat intake diary), which was completed during the training week, showed no difference between the active and control conditions. Whilst the sample size for this variable was smaller and it was only measured at one time-point, limiting power, there was no indication of training effects. This could be due to the short-term nature of this measure of meat intake, which was initiated as soon as participants started the study, leaving them with little time to prepare for reducing their meat consumption. Whilst many previous studies have reported immediate effects of RIT on reducing the intake of food or alcohol in the lab (Jones et al., 2016), it may be harder to change immediate real-world consumption of fresh food that has already been purchased (such as meat). For example, one active participant commented that the training “was good, my only problem was that over 4 days it was hard to make choices to avoid meat intake because I already had food in the fridge etc. I think training over a longer period of time I would have bought less meat”. If meat RIT takes time to translate into real-world behaviour change (e.g. reduced meat purchases), this could explain why our measure of meat intake over one month was more sensitive to detect training effects than the diary over one week. Loy et al. (2016) also found delayed effects of implementation intentions on reducing meat

intake, with significant differences between active and control groups during the fourth, but not the first week post-intervention. Similarly, Strickland et al. (2019) reported significant effects of alcohol RIT on reducing intake at two weeks follow-up, but not during the two weeks of training. Future studies of meat RIT should therefore measure meat intake for at least one month post-intervention, and/or include a pre-intervention phase with practical strategies to prepare participants for meat reduction (Bianchi et al., 2018a; 2018b). Future studies could also examine the effects of RIT on immediate meat intake measured in the lab, in order to provide a more objective measure of short-term training effects that is more aligned with previous studies of RIT.

We also hypothesised that meat RIT would lead to a greater devaluation of meat from pre- to post-training. We found a significantly larger reduction in food liking in the active than control group; however, this was a main effect and was not specific to meat. This suggests some generalization of training effects on food devaluation in active participants, particularly from meat to untrained unhealthy foods (healthy food evaluation did not change from pre- to post-training). This main effect of food RIT on food devaluation (suggesting generalization) is consistent with our previous trial (Lawrence et al., 2015a). Such generalization may be more likely if individuals form their own ‘meaningful’ categories of foods, e.g. by placing meat and untrained foods in a broader ‘unhealthy’ category (Serfas et al., 2017). This might have been facilitated by the contrasting healthy ‘go’ category being present in our training, which could have encouraged learning at a category- rather than item-level (Serfas et al., 2017; Veling et al., 2017). In addition, 73% of participants in the active condition cited health as one of their motivations for reducing their meat intake, suggesting they saw meat as ‘unhealthy’. Despite this evidence for generalization, it should be noted that the largest devaluation effect was seen for meat in the active condition, and meat was devalued significantly more than both unhealthy and healthy foods overall. Post-hoc tests confirmed that both the active and control groups showed a significant devaluation of meat over time, with this effect being (non-significantly) larger in the active group.

The devaluation of meat in control participants was not predicted but was not surprising given that they also showed a reduction in meat intake (FFQ). These findings point to non-specific effects of the control condition in reducing meat intake and liking. Decreases in consumption have previously been observed in control groups given general RIT in trials examining unhealthy snacking (Lawrence et al., 2015a), drinking (Jones et al., 2018) and smoking (Bos et al., 2019). Several studies suggest that general (non-stimulus specific) RIT

has no effects on food intake measured in a taste test (Guerrieri, Nederkoorn & Jansen, 2012; Lawrence et al., 2015b; Oomen et al., 2018). Therefore, we think that the non-specific effects seen in control groups here and elsewhere are due to other (non training-related) factors. These include the recruitment of motivated participants, asking them about why they wanted to reduce their meat intake, providing information/education (the video about animal agriculture), demand characteristics, and self-monitoring of behaviour. Some of these, such as self-monitoring, are effective behaviour change interventions (Michie, Abraham, Whittington, McAteer, & Gupta, 2009) that have previously been linked to reduced meat intake (Bianchi et al., 2018a; Loy et al., 2016). These non-specific factors may have contributed to the reduced meat intake and meat devaluation seen in both the active and control groups in this study. Consistent with this, participants in both conditions in our study commented that the educational video and self-monitoring were helpful. Whilst the larger effects seen in the active group point to training-specific effects, it is also possible that demand and motivational effects were stronger in active participants as they were repeatedly cued with images of meat in the training task, which may have reminded them of the educational video and their own meat reduction goal. Future studies could include a no-intervention control group to examine the relative contributions of specific and non-specific intervention effects of meat RIT.

In terms of the specific meat vs. control RIT effects, it is encouraging to note that the between-group effect size for reduced meat intake (Cohen's $d=0.6$), was similar to that previously shown for weight loss and reduced food intake ($d=0.5-0.6$; Allom et al, 2016; Jones et al., 2016; Lawrence et al., 2015a; Turton et al., 2016; Veling et al., 2014). It is also positive that our outcome measures (devaluation and reduced intake) were significantly correlated in active, but not control participants. The fact that these outcomes varied more systematically in the active condition (sharing ~20% of variance) is consistent with previous findings (Lawrence et al., 2015a) and supports specific intervention effects. However, the causal nature of the association between devaluation and intake remains unclear. To test for mediation effects, future studies could examine whether devaluation measured immediately after each training session predicts longer-term reductions in intake. We did not conduct mediation analyses here due to the non-normal distribution of change scores. Future research could also examine other potential mechanisms (such as improvements in 'top-down' and 'bottom-up' response inhibition to meat) in addition to devaluation to clarify the mechanism(s) underlying training effects.

Whilst devaluation and reduced intake were correlated, current findings also point to an interesting difference between them: Reduced meat intake was not associated with explicit ‘awareness’ of meat no-go associations, but the change in evaluation of trained foods (reduced for meat and increased for healthy foods) was. Whilst there are limitations in our delayed, simple measure of ‘awareness’ (Newell & Shanks, 2014; Best et al., 2016) these findings are consistent with previous research: Food RIT effects on intake appear to be relatively automatic and independent of awareness (Lawrence et al., 2015a; 2015b), whereas changes in food evaluation have been linked to a greater awareness of stimulus-response contingencies (Chen et al., 2018a; 2018b; Quandt, Chen, Holland & Veling, 2019). In the future, it would be worth increasing participants’ awareness of the ‘meat-no-go’ and ‘healthy food-go’ associations in the training task using explicit instructions or manipulations of attention to the food items, to see whether this strengthens meat RIT effects (Lee, Dingle, Griffiths, & Lawrence, 2016; Best et al., 2016; Quandt et al., 2019).

Whilst the current study shows promising findings, there were a number of limitations. First, conducting the study entirely online had some disadvantages: It led to greater attrition (24%) than in our previous trial where a researcher met participants three times (3% attrition; Lawrence et al., 2015a). It was also impossible to check understanding and adherence to the training instructions and protocol, leading to several exclusions based on low task accuracy and some missing data (e.g. for the meat diary). There was also some variation in when participants completed the post-training measures after being sent an email request, although the interval from pre- to post-training was similar in both groups (~5 weeks; active $M = 35.93$ days, $SD = 10.44$; control $M = 38.84$ days, $SD = 11.16$). However, conducting the study online was beneficial in enabling us to recruit from a wider population (Jones et al., 2014; Strickland et al., 2019) and use fewer resources, which is promising for the scalability of this intervention (Bianchi et al., 2018a).

A second limitation was that only self-report measures were used and these can be prone to bias (Schoeller et al., 2013). Previous studies of RIT for drinking, smoking and eating have shown greater specific intervention effects on objective measures (weight-loss, reduced consumption in the lab) than on self-report measures (Bos et al., 2019; Jones et al., 2018; Lawrence et al., 2015a; Veling et al., 2014). It is difficult to obtain objective measures of meat intake but, in addition to measuring actual intake in a lab study (see above), future studies could try to measure self-reported intake more accurately by using more detailed food diaries completed at multiple time-points (Lawrence et al. 2015a; Loy et al., 2016), or by

using ecological momentary assessment (e.g. Thomas, Doshi, Crosby & Lowe, 2011). It may also be useful to examine changes in the number of days on which meat is consumed, given campaigns such as ‘Meat Free Mondays’. As this was a preliminary study and the training was already relatively time-consuming (~40 minutes), we did not want to overburden participants with detailed dietary assessments. However, the use of multiple food diaries measuring all food and drink consumed over 24 hours (such as the National Cancer Institute’s automated ASA24; Thompson et al., 2015) would be useful to examine the specificity of training effects. For example, one could compare changes in individuals trained to inhibit to HFSS foods vs. meat, and also measure changes in the intake of healthy foods (‘go’-trained and untrained) to examine whether ‘no-go’ foods are replaced with healthier alternatives.

We should also note that participants in this study were self-selected and were motivated to reduce their meat intake, as shown by their completion of the relatively burdensome experimental procedure. Current findings may therefore not be generalizable to the wider population of people who wish to reduce their meat intake. Future studies should aim to replicate these results in samples that are more diverse. For example, it would be interesting to examine the effectiveness of meat RIT in individuals who have been encouraged to reduce their meat intake due to high cholesterol or heart disease. It would also be useful to measure additional factors that may moderate training effects, such as participants’ levels of motivation and whether their goal is to reduce meat intake or give it up altogether. In addition, we did not measure participants’ body mass index (BMI) in this study but this would be useful to include in the future, both as an outcome measure and to allow better characterization of the sample.

We do of course acknowledge that this intervention is one of many that would be required to reduce meat intake to the low levels required for meaningful environmental and health benefits (Willet et al., 2019). Strategies will need to target multiple factors within the food system, from changing individual awareness and attitudes, to modifying the food environment through product reformulation, increasing the availability of non-meat alternatives and reducing portion sizes of meat products (Bianchi et al., 2018a; 2018b; Stubbs et al., 2018). Our findings suggest that meat RIT is one tool that individuals could use to support their attempts at meat reduction. Its advantages are that it is simple, free and highly scalable. Feedback from our participants suggested reasonable acceptability, which could be improved with a greater variety of images, a more engaging task, and delivery via a

smartphone-app; “I could see it working quite well as an app - before going to a restaurant you could do it, which would maybe persuade you to order vegetarian options.” We have already developed and released an app based on similar feedback from our previous study (Lawrence et al., 2015a). Our “Food Trainer” (FoodT) app allows users to select ‘no-go’ food categories from a range of 15 (including meat and fast food), it includes a greater variety of images, and the task is shorter and includes game features (points). Since its release in 2017, it has been downloaded more than 83,000 times, demonstrating its scalability. Users of the app show small-to-medium effects on changes in self-reported weight and snacking frequency (Lawrence, Van Beurden, Javaid, & Mostazir, 2018). Future research should conduct large-scale RCTs to examine longer-term effects of meat RIT, delivered online or via the app. It would also be interesting to see whether combining meat RIT with other interventions, such as mental contrasting with implementation intentions (Loy et al., 2016) increases the effect size. This could build on recent attempts to combine multiple self-regulation techniques for reducing HFSS food intake into one digital intervention (e.g. Van Beurden et al., 2019; Stice et al., 2017). If similar digital interventions can help individuals to reduce their meat intake, it would be beneficial for the environment, human health and animal welfare.

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