Food product health warnings promote dietary self-control through reductions in neural signals indexing food cue reactivity

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ABSTRACT

Modern societies are replete with palatable food cues. A growing body of evidence suggests that food cue exposure activates conditioned appetitive physiological and psychological responses that may override current metabolic needs and existing eating goals, such as the desire to maintain a healthy diet. This conditioned response results in unhealthy dietary choices and is a contributing factor in the current obesity epidemic. Prime based obesity prevention measures such as health warnings at point-of-sale or on product packaging may have the potential to counteract the influence of the obesogenic environment at the crucial moment when people make food purchasing or consumption decisions. Existing research into the efficacy of these intervention strategies has predominantly employed self-report and population level measures, and little evidence exists to support the contention that these measures counteract food cue reactivity at the time of decision making. Using a dietary self-control priming paradigm, we demonstrated that brief exposure to food product health warnings enhanced dietary self-control. Further, we analysed electroencephalographic correlates of selective attention and food cue evoked craving (N1, P3, LPP) to show that health warning exposure reduced the automatic appetitive response towards palatable food cues. These findings contribute to existing evidence that exogenous information can successfully prime latent goals, and substantiate the notion that food product health warnings may provide a new avenue through which to curb excessive energy intake and reduce rising obesity rates.

1. Introduction

The relationship between conscious intentions to alter behaviour and observed behavioural change is well documented (Sheeran et al., 2016). However, it is widely accepted that factors outside our consciously stated intentions can have a considerable influence on our behaviour (Inauen et al., 2016). For example, the highly palatable food cues that are ubiquitous in modern Western and Westernised societies are capable of triggering conditioned appetitive responses such as increased salivation (Rogers and Hill, 1989) and neural activity in gustatory and reward-relevant brain areas (Simmons, 2005). This collection of physiological and cognitive responses is experienced as craving, and has the potential to override homeostatic signalling of current metabolic needs and previous conscious decisions regarding eating behaviour, such as healthy eating goals (Bilman et al., 2017). As such, food cue reactivity has been linked to increased food consumption (Larsen et al., 2012), weight gain (Murdaugh et al., 2012) and may be

exacerbating rising obesity rates (Morris et al., 2015).

The increase in environmental and habitual factors that bias people towards unhealthy eating has driven calls for prime-based intervention strategies that may cue latent health goals at the time of decision-making (Cohen and Lesser, 2016) and prevent momentary lapses in self-control. One such intervention that has received legislative attention is the proposal to require health warning messages on certain food products (Popova, 2016). Nonetheless, there is still insufficient research on whether health warnings can effectively prime healthy eating goals, and whether exposure to health warnings leads to detectable changes in neural processing of food items. The present study examined electro-encephalographic (EEG) correlates of cognitive processes related to dietary self-control and food cue reactivity after priming with health warnings in order to test this idea.

Food cue reactivity research has provided evidence that the neural processing of food stimuli is influenced by choice-relevant stimulus characteristics and the individual's current motivational state (amongst

Abbreviations

AUD	Australian dollar
DSC	dietary self-control
EEG	electroencephalogram
ERP	event related potential
HW	health warning
LPP	late positive potential
SE	standard error
SD	standard deviation

other factors; Asmaro and Liotti, 2014). For example, early, automatic attentional processes reflected in the occipital N1 event-related potential (ERP) component responded to the energetic value of food (Toepel et al., 2009). This attentional filtering process is thought to reduce the deployment of neural resources for goal-irrelevant items and is therefore influenced by the match between stimulus characteristics and the current decision-making goal (Harris et al., 2013). Similarly, the parietal P3 and late positive potential (LPP) are mid- to late-latency ERP components that have been studied extensively in substance cue reactivity and have consistently been found to index the subjective cue-induced craving response (Littel et al., 2012). This craving response is subject to top-down cognitive regulation (Meule et al., 2013), making these ERP components a valuable neural index for the study of the ability of food product health warnings to counteract appetitive food cue reactivity.

We used a dietary self-control priming paradigm in which participants provided health and taste ratings of snack food items, and then made choices regarding which foods to eat at the experiment's conclusion, prior to- and post-exposure to health warning messages (Rosenblatt et al., submitted). Using participants' subjective health and taste ratings we classified trials into self-control trials (where health and taste ratings conflict) and non-self-control trials (no conflict between health and taste), allowing us to test the extent to which health warnings increase dietary self-control. We also tested whether observed changes in self-control are driven by differences in the perceived palatability or health qualities of food stimuli. Using ERPs, we additionally investigated whether neural attention regulation and craving responses to food stimuli were modulated accordingly, and whether these changes were predictive of observed changes in dietary self-control. We hypothesised that participants would display increased dietary self-control after viewing health warnings, and this change would be reflected in an up-regulation of attention towards healthy food items and/or a down regulation of attention towards unhealthy items. We further hypothesised that after viewing health warnings, brain signals correlating with subjective cue-induced craving would be increased in response to unpalatable/healthy food items and diminished in response to palatable/unhealthy food items. Lastly, we hypothesised that food-stimulus-evoked brain signals that were influenced by health warning exposure would be associated with successful dietary self-control.

2. Methods

2.1. Participants

Ninety-six right-handed English-speaking participants (M age = 22.64 years, SD = 4.94, M BMI = 21.54, SD = 3.09, BMI range = 16.65–34.71, 66 female) with normal or corrected-to-normal vision were recruited via advertisements. The behavioural data presented here have been used in analyses that have been reported elsewhere (Rosenblatt et al., under review). Exclusion criteria were any history of eating disorders, or any medical, ethical, religious or other belief or condition that prevented them from eating the food items presented in the study. Fourteen participants were excluded post-hoc

due to persistent artifacts in the EEG data. Three participants were removed due to technical problems with data recording. The remaining 79 participants' (M age = 22.91 years, SD = 5.31, M BMI = 21.65, SD = 3.25, BMI range = 16.65–34.71, 52 female) data were used in the analyses. The University of Melbourne Human Research Ethics Committee approved all study procedures (No. 1443258), and participants gave written informed consent before participating.

2.2. Materials and stimuli

Snack food stimuli were 100 color pictures of snack foods presented on a white background. All food images measured 500×500 pixels, subtending at a visual angle of $13.4° \times 13.4°$. Food stimuli were selected based on ratings provided by an independent sample of 259 participants (M age = 27.56 years, SD = 10.54, 183 female) and had been used in a previous study by our group (Rosenblatt et al., under review). Taste, health and familiarity ratings were recorded for 492 snack food items using 6-point scales. The 100 food items selected for the current study met the following criteria: they collectively encompassed the full range of health and taste ratings such that they could be divided into four groups defined by these attributes (healthy/tasty, healthy/not-tasty, unhealthy/tasty, and unhealthy/not-tasty); displayed a low degree of interdependence between taste and health ratings across items ($r = 0.17$); exhibited health and taste ratings that varied minimally across participants (SD < 1.5); and on average were familiar to participants (mean > 3 on a scale from 1 = "not at all familiar" to 6 = "extremely familiar"). The chosen food items included chips, chocolate bars, biscuits, nuts, fruits and vegetables.

Twenty five health warning (HW) messages were created based on the National Health and Medical Research Council Dietary Guidelines for Australians (NHMRC, 2013) and were consistent with current epidemiological evidence. As described in Rosenblatt et al. (under review), four variants were created for each health warning topic: text-only/positive message frame, text-only/negative framing, image-and-text/positive framing, and image-and-text/negative framing, and each participant was exposed to health warnings from one of these groups. In order to select the best exemplars of the health warnings that were created, a second independent sample of 95 participants (M age = 28.18 years, SD = 10.85, 73 female) provided perceived efficacy ratings of these sample health warnings on a nine-item scale adapted from existing health communication efficacy questionnaires (Hammond et al., 2007; Nonnemaker et al., 2015). The scale items assessed the extent to which participants thought each warning would motivate healthier dietary choices (e.g. "This health warning is effective", "This health warning would prompt me to purchase a healthier snack") and related constructs such as whether they believed the content of the warning or whether it was likely to capture their attention (e.g. "This health warning grabs my attention", "This health warning is worth remembering", "This health warning makes a strong argument for eating a healthy diet"). Participants responded to these questions on a 5-point scale ranging from "Strongly Disagree" to "Strongly Agree". The 10 health warning messages that received the highest average perceived efficacy ratings across all four variants were selected for use in the experiment. Twenty control stimuli were created by randomly sorting the pixels of the chosen image-and-text HWs horizontally and replacing the text with pronounceable non-words of equivalent length (Rastle et al., 2002). Text-only health warnings were 500×200 pixels (subtending at a visual angle of $13.4° \times 5.3°$), while image-and-text health warnings were 500×500 pixels ($13.4° \times 13.4°$).

For the purposes of conserving statistical power for the present analyses, all health warning variants were grouped together, resulting in one health warning group and one control group. This means that while different participants were exposed to different health warning variants (13 participants per variant on average), the health warning topic of the messages featured in these warnings was consistent for all participants. For more information regarding the characteristics of the