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Health warnings promote healthier dietary decision making: Effects of positive versus negative message framing and graphic versus text-based warnings

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ABSTRACT

Food product health warnings have been proposed as a potential obesity prevention strategy. This study examined the effects of text-only and text-and-graphic, negatively and positively framed health warnings on dietary choice behavior. In a 2 × 5 mixed experimental design, 96 participants completed a dietary self-control task. After providing health and taste ratings of snack foods, participants completed a baseline measure of dietary self-control, operationalized as participants' frequency of choosing healthy but not tasty items and rejecting unhealthy yet tasty items to consume at the end of the experiment. Participants were then randomly assigned to one of five health warning groups and presented with 10 health warnings of a given form: text-based, negative framing; graphic, negative framing; text, positive framing; graphic, positive framing; or a no warning control. Participants then completed a second dietary decision making session to determine whether health warnings influenced dietary self-control. Linear mixed effects modeling revealed a significant interaction between health warning group and decision stage (pre- and post-health warning presentation) on dietary self-control. Negatively framed graphic health warnings promoted greater dietary self-control than other health warnings. Negatively framed text health warnings and positively framed graphic health warnings promoted greater dietary self-control than positively framed text health warnings and control images, which did not increase dietary self-control. Overall, HWs primed healthier dietary decision making behavior, with negatively framed graphic HWs being most effective. Health warnings have potential to become an important element of obesity prevention.

1. Introduction

Global estimates of combined overweight and obesity prevalence rose from 31% to 46% between 1980 and 2008 (Stevens et al., 2012). In contrast, the global prevalence of tobacco smoking decreased from 26% to 19% over the same period (Ng et al., 2014). This reduction in smoking rates has, in most countries, been attributed to comprehensive and multifaceted tobacco control policies (Ver Bilano et al., 2015). One component of this strategy – health warning (HW) messages on tobacco products and at point-of-sale – offers a high-exposure, low-cost opportunity to communicate the health risks of tobacco products to consumers and has been used successfully in tobacco control (Monárrez-Espino, Liu, Greiner, Bremberg, & Galanti, 2014). The causes of obesity reflect a complex interplay between environmental, biological and lifestyle factors. However, there is convincing evidence that a high intake of energy-dense, micronutrient-poor food is one important risk factor (Swinburn, Caterson, Seidell, & James, 2004). Accordingly, HWs on such foods have been proposed as a public health intervention to discourage their consumption, to help reduce obesity prevalence. However, little is known about the efficacy of HWs for prompting consumers to make healthier dietary choices.

HWs may promote healthier dietary decision making in two ways.

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Firstly, HWs can be used to educate consumers about the potential harms of a product. Both theoretical (Strahan et al., 2002) and empirical (Borland et al., 2009) work indicates that altering beliefs and attitudes about health-relevant behaviors and the risks associated with these behaviors drives behavioral change by engendering conscious intentions to change. Secondly, cueing interventions may be effective for addressing non-intentional influences on behavior such as habits, impulses and unconscious goals (Papies, 2016). These interventions aim to make conscious intentions salient at the time of decision making by priming latent health goals (Papies & Hamstra, 2010). Product or point-of-sale HWs are ideally suited to act as healthy eating primes, as they are necessarily present at the time of food choice decision making.

Some promising experimental studies showing that HWs reduce intentions to purchase unhealthy food products currently exist (Roberto, Wong, Musicus, & Hammond, 2016; VanEpps & Roberto, 2016). For example, Bollard, Maubach, Walker, and Mhurchu (2016) showed that HW messages reduced preferences for, and reported likelihood of purchasing, sugar sweetened beverages. However, no study to date has investigated the extent to which HWs prime healthy eating goals, and whether this priming promotes healthy eating by increasing the likelihood that individuals will act on these healthful intentions at the time of decision making. Furthermore, much of our understanding of the influence of HWs on behavior comes from self-report survey-based studies and studies targeting smoking (Noar et al., 2016a; Noar et al., 2016b). Survey-based approaches are limited in their ability to investigate the efficacy of HWs for priming healthy dietary choices, as they generally do not allow for the direct measurement of behavior as it is enacted. Furthermore, it is unclear how generalisable insights from tobacco control research are for obesity prevention.

A related question concerns the attributes of HWs that make them effective healthy eating primes. In the present study, two dimensions are of primary interest. The first is the effectiveness of HWs that feature an image and text (henceforth referred to as graphic HWs) relative to text-only HWs. Tobacco HWs were introduced in the 1960s, featuring general text-only messages on the side of packs (Hiilamo, Crosbie, & Glantz, 2013). Similarly, the obesity prevention HWs that have been proposed (e.g. California; Calif. Legis. S., 2014; and New York State; N. Y. Legis. S., 2015) or implemented (Corvalán, Reyes, Garmendia, & Uauy, 2013; Papies & Hamstra, 2010) to date, largely feature simple text-based messages only. However, behavioral and survey evidence suggests that graphic HWs are superior to text-only warnings on numerous outcomes (Hammond, 2011; Noar et al., 2016a). For example, the smoking literature has demonstrated that graphic anti-tobacco HWs were more likely to be attended to, read, discussed, and remembered than text warnings (Borland et al., 2009), and were associated with more accurate perceptions of the risk of, and greater intentions to abstain from, harmful behaviors (Noar et al., 2016b). Over the past half-century, anti-tobacco HWs have progressed to covering most of the pack, conveying definitive messages linking smoking with specific diseases, and featuring color pictures (Hiilamo et al., 2013). It is therefore important to establish whether the superior efficacy of graphic HWs over text-only warnings extends to diet related HWs.

A second dimension is message framing (positive vs. negative; Wansink & Pope, 2014). Positively framed messages focus on the health benefits of abstaining from harmful behavior, while negatively framed warnings focus on the negative consequences of engaging in harmful behavior. While negative message frames are typically favoured by public health professionals and are used in most anti-tobacco HWs (Hammond, 2011), the literature suggests that the effect of framing may depend on the characteristics of the population under examination and the specific behavior being targeted (Mays et al., 2014). For example, Goodall and Appiah (2008) showed that negatively framed tobacco health warnings were associated with increased perceived efficacy and reduced intentions to smoke in a sample of adolescent tobacco users, relative to positive frames. However, a number of studies looking at physical activity promotion messages have found that gain framed messages are associated with increased behavior change self-efficacy and improved behavioral outcomes (Latimer, Brawley, & Bassett, 2010a; Latimer et al., 2010b). Similarly, a meta-analysis investigating message framing effects in a range of health behaviors found support for the use of positive frames when targeting preventive behaviors such as exercising and eating healthy foods (Gallagher & Updegraff, 2012). The relationship between message framing and communication efficacy therefore warrants further research, particularly in the context of obesity prevention.

The present study used a novel dietary self-control priming paradigm in which participants chose snack foods to consume at the end of the experiment, prior to- and post-, exposure to HW messages. We aimed to assess the efficacy of text and graphic HWs featuring positive and negative message frames for promoting healthy dietary choices. It was hypothesised that participants would display increased dietary self-control after being exposed to HWs. Additionally, it was hypothesised that graphic HWs would lead to greater increases in dietary self-control than text-based warnings. Lastly, this study sought to explore whether there were any systematic differences in the effect of positive versus negative message framing on dietary self-control.

2. Methods

2.1. Participants

Ninety-six right-handed English-speaking participants (*M* age = 22.64 years, *SD* = 4.94, 66 female) were recruited via advertisements at the University of Melbourne. As the paradigm used here has not been used before, effect size estimates could not be attained. This sample sized was deemed sufficient based on past studies of a similar nature (cf. Harris, Hare, & Rangel, 2013). Participants were excluded from participation if they were under the age of 18, were pregnant, had any history of eating disorders, were restricting their diet or had any medical, ethical, religious or other belief or condition that would prohibit them from eating the foods presented in the study. These exclusion criteria were listed on the study participation advertisement, allowing participants to self-select based on their eligibility to take part. For this reason, all participants who contacted us were able to be included in the study. The University of Melbourne Human Research Ethics Committee approved all study procedures (1443258). All participants provided written informed consent before participation.

2.2. Materials and stimuli

Participants were presented with color pictures of 100 snack foods on a white background (Fig. 1a). Foods were selected from a prior pilot study of 259 participants (*M* age = 27.56 years, *SD* = 10.54, 183 female) who rated 492 different snack foods on healthiness, tastiness and familiarity using 6-point scales (1 = Not at all, 6 = Extremely). Foods for the current study: (1) spanned the full range of health and taste attributes and could be divided into four equally sized groups (high health/high taste, high health/low taste, low health/high taste, and low health/low taste), (2) exhibited a low degree of correlation between the tastiness and healthiness attributes across items, (3) showed low variance on healthiness and tastiness across participants (SD $<$ 1.5) and (4) were familiar to participants (mean $>$ 3). Food items were presented in both the pilot study and the present study in the form that they would appear in a supermarket or convenience store environment (e.g. chocolate bars and other packaged items were displayed with packaging) in order to capture the true perceptual characteristics of these items as they typically appear during purchase and consumption decisions. The chosen food items included fruits, nuts, vegetables, chips, biscuits and chocolate bars (see Supplemental Materials, Figs. S1–S4).

HW stimuli were created based on current epidemiological evidence and were consistent with the National Health and Medical Research

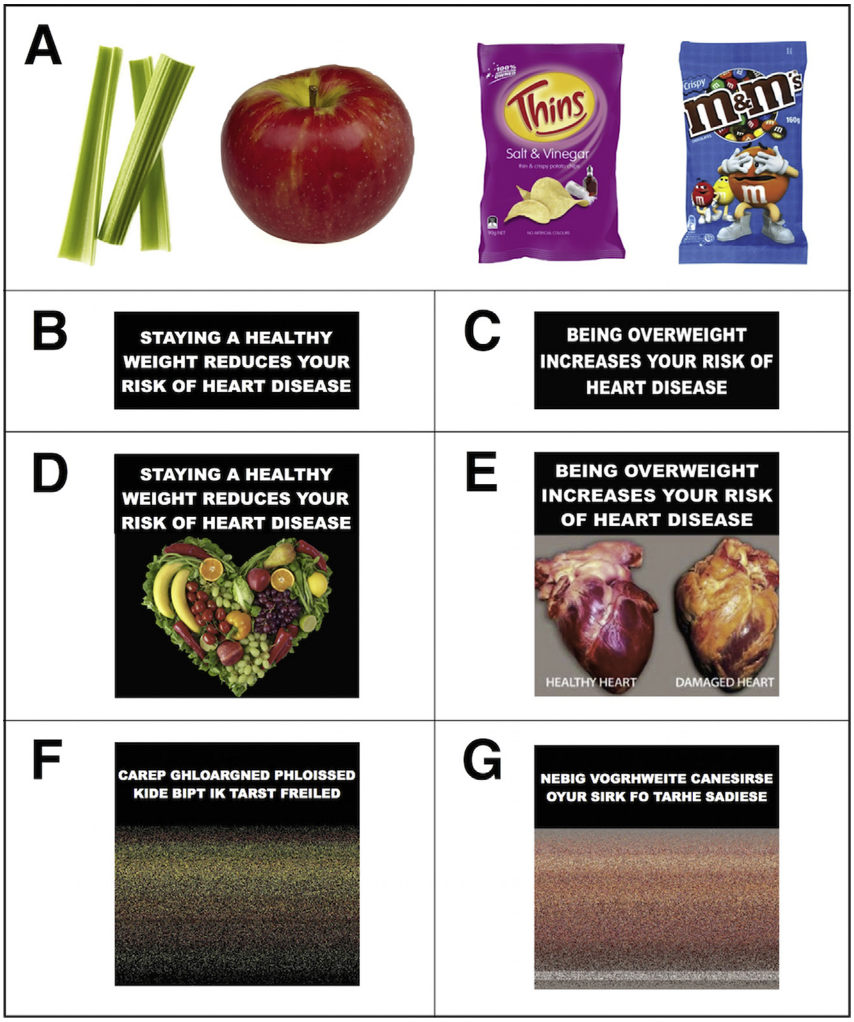

Fig. 1. Examples of (a) food cue stimuli; and health warning stimuli formats: (b) text-only/positively-framed; (c) text-only/negatively-framed; (d) text and graphic/positively-framed; (e) text and graphic/negatively-framed; and (f–g) control stimuli.

Council Dietary Guidelines for Australians (2013, pp. 1–226). Resultantly, some HW messages focused on the relationship between diet and health, while others focus on the link between excess body weight and health, as these are the relationships that have been established in the literature. Twenty-five diet-related HW messages were created, then presented in four different formats: text-only/positively framed, text-only/negatively framed, graphic/positively framed, and graphic/negatively framed, resulting in 100 HWs.

A pilot study in which 95 adults (*M* age = 28.18 years, *SD* = 10.85, 73 female) rated the perceived effectiveness of the 100 sample HWs on a nine-item scale adapted from existing studies (Hammond et al., 2007; Nonnemaker, Choiniere, Farrelly, Kamyab, & Davis, 2015), was used to identify the messages that were perceived as most effective across all four formats. The 10 messages (see Supplemental Materials for full list) that showed the highest average perceived efficacy ratings across all four formats were selected (resulting in 40 HW stimuli; Fig. 1b–e for examples). Participants in both pilot studies were Australian residents recruited via advertisements at the University of Melbourne.

Twenty control stimuli (Fig. 1f–g) were created by randomly sorting the pixels of the graphic variants of the HWs horizontally. Next, to ensure that the content of these HWs was sufficiently obscured from the control group participants, a noise filter was applied to the images. Captions were replaced with pronounceable non-words of equivalent length, taken from the ARC Nonword Database (Rastle, Harrington, & Coltheart, 2002). Stimulus presentation and data acquisition were conducted using MATLAB (R2014b; The Math Works) and Psychtoolbox (Brainard, 1997).

2.3. Procedure

Each participant completed a single experimental session, conducted at the University of Melbourne Parkville campus. Participants were informed that they would be taking part in a dietary decision making experiment, but no mention was made of health warnings or any other dietary interventions at the beginning of the session. To control for hunger disparities, participants were instructed to refrain from eating or drinking (except water) for at least four hours before the experiment (cf. Harris et al., 2013). Sessions were held at each of three time windows during testing days and participants may have had different fasting hours as a result of this. However, group allocation was randomized, with the intention that hunger levels and fasting hours would balance out across the sample. To facilitate assessment of whether this was the case, participants rated their hunger on an eight-point Likert scale (1 = not at all hungry, 8 = extremely hungry) and indicated the number of hours since they last ate.

The experiment consisted of a computer-based task with four stages (Fig. 2): the rating, unprimed decision, priming, and primed decision stages. The rating stage and both decision stages were identical for all participants. In the priming stage participants were randomly assigned to one of the five HW conditions: text-only/positively framed messages,

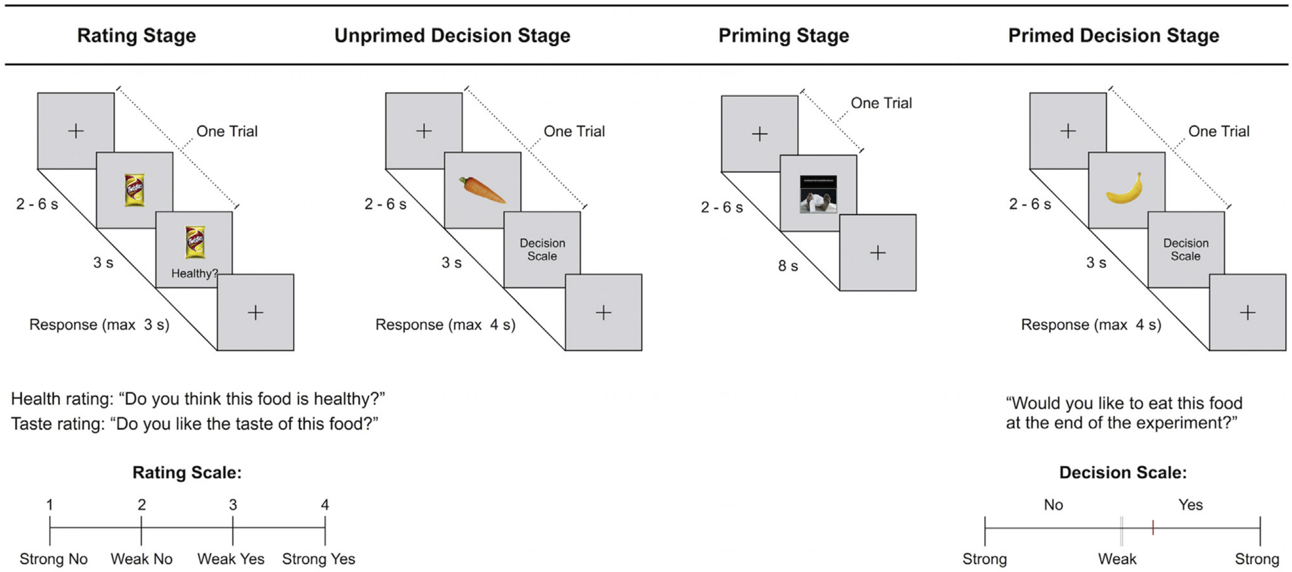

Fig. 2. Schematic diagram of the four stages of the experiment, presented in chronological order. Participants were divided into five different health warning format groups for the priming stage; all other stages were identical for all participants.

text-only/negatively framed messages, graphic/positively framed messages, graphic/negatively framed messages, and message free control images. Between each stage participants took a short break, after which the subsequent stage was explained. Most importantly, the priming stage was only explained after the first decision stage was completed, and the wording used to describe this stage to all participants (regardless of HW group allocation) was "In the next stage, you will see a series of images accompanied by text, you should attend to these images when they are presented". Participants were informed that one food item would be selected based on the responses they gave during the decision stages of the experiment, that this item would be given to them on completion of the experiment and they would be able to eat it while completing the questionnaires and debriefing at the end of the session. This procedure was intended to ensure that participants' decisions reflected their true preferences, as they knew that any item they chose could be selected and thus each decision they made could be considered a 'real' dietary choice. Electroencephalogram, a non-invasive method for recording the electrical activity of the brain, was recorded for the duration of the experiment. Electroencephalogram results will be reported in a separate publication.

Rating Stage. In each trial, participants fixated on a central cross for a random interval of two to six seconds. They were then shown one of the 100 food items. After three seconds, a response scale featuring one of two questions ("Do you like the taste of this food?" or "Do you think this food is healthy?") appeared below the food item on the screen for a further three seconds. Participants registered their response on a four-point Likert-scale (1 = Strong No, 2 = Weak No, 3 = Weak Yes, 4 = Strong Yes). Ordering of response options reversed randomly from trial to trial. Participants rated each food item on both attributes, yielding 200 trials. Food items were displayed and paired with attribute ratings in random order between participants. Trials were presented in four blocks of 50. Between each block participants took a self-paced break.

Based on the health and taste ratings, each food item was categorized into one of five groups individually for each participant: Healthy-Tasty, Healthy-Not Tasty, Unhealthy-Tasty, Unhealthy-Not Tasty, and undefined items (for which one or both ratings were not provided in the allotted time window; 3.6% of all items). Food items were then randomly allocated to the unprimed and primed decision stages, such that 50% ± 1 of the items in each of these health-taste groupings appeared in each decision stage, with each decision stage featuring 50 items total.

Unprimed Decision Stage. The unprimed decision stage comprised a single block of 50 trials. In each trial a jittered (2–6 s) fixation cross was presented centrally, followed by a food item for three seconds and then a response scale for four seconds. A continuous response scale was used, ranging from 'Strong No' to 'Strong Yes', with 'Weak No' and 'Weak Yes' bordering the midpoint of the scale, and appeared below the question "Would you like to eat this food at the end of the experiment?" The position of the 'Yes' and 'No' options was randomly counterbalanced from trial to trial. Participants responded by moving a graphical slider using a computer mouse and were unable to select the midpoint of the scale. This required participants to make a binary decision as to whether they would eat the displayed stimulus while also indicating the strength of their response. For off-line analysis, the scale was divided into 201 bins and the range of responses was coded as running from −100 to −1 ('No' responses) and then from 1 to 100 ('Yes' responses).

Priming Stage. The priming stage consisted of 10 trials, where participants fixated on a central cross (2–6 s jitter), and were then presented with one of the 10 HWs representing their assigned HW condition (or control images for participants in the control group) presented centrally for eight seconds. Each HW (or control image) was shown once, in individually randomized order. Participants were instructed to attend to and read the HW messages (including those in the control condition). To ensure that participants attended to HWs, participants were told that on a small proportion of trials a red border would appear around the HW, in this case they were to press the space bar (at which point the border would turn green). This attention check occurred on a random three trials out of the total 10, six seconds after onset, to prevent deliberate disengagement from viewing HWs (Maynard et al., 2014). No participant failed more than one attention check.

Primed Decision Stage. The primed decision stage was identical to the unprimed decision stage, except that it featured the remaining 50 food items.

After completing the experiment, one of the food items the participant had indicated they would like to eat was randomly drawn, and given to them. Participants were allowed to eat this item while completing final questions on demographics and dietary habits. To confirm the validity of the control condition, participants were then asked to explain what they understood to be the purpose of the study. Control group participants reliably responded that the study was designed to investigate dietary decision making (or similar), whereas HW group participants responded that we were testing the efficacy of HWs.

Finally, participants were verbally debriefed on the study's purpose and remunerated AUD$20.

2.4. Measures and analysis

For each participant, a measure of dietary self-control (DSC) was calculated for both the primed and unprimed decision stages, by dividing decision stage trials into self-control trials and non-self-control trials. Self-control trials constituted trials where participants had previously rated a food item as either healthy-not tasty or unhealthy-tasty. For these trials, successful dietary self-control was defined as 'Yes' decision responses to the question "Would you like to eat this item at the end of the experiment?" for healthy-not tasty items, or 'No' responses for unhealthy-tasty items, because the subjective health and taste attributes of the foods featured in these trials were in conflict, requiring dietary self-control when making healthier decisions. Trials featuring healthy-tasty or unhealthy-not tasty items were considered non-self-control trials, as subjective health and taste attributes concurred, so exercising dietary self-control was unnecessary. DSC was then calculated by taking the continuous decision responses for healthy-not tasty trials, and the reverse coded continuous decision responses in unhealthy-tasty trials. For all self-control trials in each decision stage, this DSC measure was then included as a dependent variable in subsequent analyses.

One-way analyses of variance (ANOVA) for continuous variables, Kruskal-Wallis tests for ordinal data, or chi-squared tests for proportions were conducted to check for differences in individual and demographic factors between HW groups. A *p*-value of < 0.05 in these tests was used as grounds to include the corresponding variable as a covariate in subsequent analyses.

Effects of HW condition, experimental decision stage and condition-by-stage interaction on DSC were assessed via linear mixed effects modeling using the lme4 package in R (Bates, Mächler, Bolker, & Walker, 2015). Participants and stimuli were specified as random intercepts in order to control for the variance associated with these factors without data aggregation. These models tolerate the unequal trial numbers necessitated by our experimental design. We assessed model fit by conducting log-likelihood ratio tests comparing the full model with alternative models that lacked the predictor variable or variables of interest (backward selection). Satterthwaite degrees of freedom approximation was used to calculate *p*-values. Bonferroni adjusted post-hoc comparisons between groups that displayed a significant priming effect were conducted using the phia package in R (De Rosario-Martinez, 2015). See Supplemental Materials for additional analyses testing whether HW exposure altered dietary choices during non-self-control trials (pages 10–12), and investigating the influence of the HW conditions on dietary choices as a function of health and taste separately, rather than in combination as in the DSC measure used here (pages 12–18).

3. Results

3.1. Sample demographics

Descriptive statistics for HW group and whole-sample demographic characteristics are summarized in Table 1. No significant differences were detected between the five HW groups in any of the demographic, weight, hunger or dietary consumption measures. Thus these variables were not included as covariates in subsequent analyses.

3.2. Dietary self control

To understand how the different HW conditions influenced DSC, we constructed a linear mixed-effects model to explain DSC using HW conditions, experiment stage, and condition-by-stage interaction as fixed effects and modeled participants and stimuli as random intercepts. Following a backward selection approach for fixed effects, we removed the condition-by-stage interaction effect from the model, which significantly reduced the goodness of fit as indicated by likelihood ratio test ($\chi^2_{(4)} = 35.73, p < 0.001$). Following the same approach, we found a significant main effect of experiment stage ($\chi^2_{(1)} = 30.79, p < 0.001$) but not HW condition ($\chi^2_{(4)} = 6.02$, $p = 0.2$). These results show that the effect of the different HW conditions on DSC differed across experimental stages, indicating that priming with HW images altered dietary decision behavior, and that the magnitude of this effect differed between HW groups.

Significant differences in primed DSC were observed in the text-negative group ($\beta = 11.08$, $SE = 4.42$, $p < 0.05$; estimated 5.54% increase), the graphic-positive group ($\beta = 10.83$, $SE = 4.21$, $p < 0.05$; estimated 5.42% increase), and the graphic-negative group ($\beta = 23.35$, $SE = 4.35$, $p < 0.001$; estimated 11.68% increase), relative to the unprimed DSC displayed by the control group. No other significant differences in DSC across HW conditions or experiment stages were detected (Table 2).

To further explore these effects, pairwise post-hoc contrasts were conducted between each of the HW groups that displayed a significant change in DSC between experiment stages, using Bonferroni adjusted *p*-values. The graphic-negative group displayed a significantly greater change in dietary self-control relative to the graphic-positive group ($\chi^2_{(1)} = 6.5$, $p = 0.033$) and also relative to the text-negative group ($\chi^2_{(1)} = 5.82$, $p = 0.047$). The graphic-positive group and text-negative group did not differ significantly ($\chi^2_{(1)} = 0.003$, $p = 1$).

Additionally, there was a notable difference between the estimate of DSC for the text-positive group in the unprimed condition relative to the unprimed control group ($\beta = 16.94$, $SE = 9.23$, $p = 0.07$) indicating a slightly (but not-significantly) higher baseline DSC for participants in this group compared to other groups. See Fig. 3 for a plot of the change in DSC from the unprimed to primed decision stages across HW groups.

See Supplemental Materials for results of additional analyses. In summary, the key findings of these analyses were as follows: Firstly, HW exposure had no effect on dietary choices during non-self-control trials. Second, the increased DSC displayed by graphic-positive and text-negative group participants after priming was driven by an increased propensity to choose items perceived as healthy. Lastly, the improved DSC displayed by graphic-negative group participants was driven by both an increased propensity to choose healthy items and a reduced tendency to choose items perceived as tasty.

4. Discussion

This study found that HWs effectively promoted healthier dietary choices for snack foods using a behavioral measure of dietary self-control. Consistent with past studies in tobacco control (Hammond, 2011), graphic warnings were more effective for promoting behavioral change than text only warnings. Results further indicated greater efficacy for negatively framed HWs, relative to positively framed warnings.

The results of this study complement a large body of evidence from tobacco control showing that graphic HWs promote behavioral change more successfully than text based warnings (Nan, Zhao, Yang, & Iles, 2014; Noar et al., 2016a; Noar et al., 2016b). However, it bears noting that (negatively framed) text-only HWs also promoted increased dietary self-control in this study. This is promising as text-based warnings have generally constituted the first step in implementing HW policies (Shanahan & Elliot, 2009), and may be more feasible to implement initially than stronger graphic warnings.

Negatively framed HWs promoted healthier dietary choices more effectively than positively framed HWs in this experiment, a result consistent with most existing tobacco control HW studies (Hiilamo et al., 2013). However, in past research on health-related behaviors other than smoking the verdict on when positive versus negative message frames are most effective remains equivocal. Across a range of

Table 1
Characteristics of participants by health warning groups.

	Total Sample (n = 96)	Text-Negative (n = 16)	Text-Positive (n = 16)	Graphic-Negative (n = 16)	Graphic-Positive (n = 16)	Control (n = 32)	$F_{(4, 91)}$	*p*
	Mean (SE [a])	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)		
Age	22.6 (0.5)	24.2 (1.28)	20.9 (0.52)	24.8 (2.1)	21.8 (0.88)	22 (0.66)	1.95	0.11
Body mass index (kg/m^2)	21.5 (0.31)	22.1 (0.98)	21.9 (0.74)	21.9 (1.06)	21.4 (0.59)	21 (0.42)	0.49	0.74
Hours fasted	6.91 (0.47)	5 (0.84)	7.81 (1.21)	6.38 (1.22)	7.56 (1.26)	7.34 (0.83)	1.04	0.39
Initial hunger rating (1–8)	4.65 (0.18)	4.88 (0.49)	4.44 (0.47)	5.38 (0.35)	4.31 (0.46)	4.44 (0.28)	1.12	0.35
	***N* (%)**	***n* (%)**	***n* (%)**	***n* (%)**	***n* (%)**	***n* (%)**	$\chi^2_{(4)}$	***p***
Sex								
Female	66 (68.8)	9 (56.3)	13 (81.3)	10 (62.5)	11 (68.8)	23 (71.9)	2.76	0.6
Male	30 (31.3)	7 (43.8)	3 (18.8)	6 (37.5)	5 (31.3)	9 (28.1)		
Vegetable consumption								
≤ 2 serves per day	35 (36.5)	5 (31.3)	4 (25)	5 (31.3)	8 (50)	13 (40.6)	2.59	0.63
3 serves per day	32 (33.3)	6 (37.5)	7 (43.8)	4 (25)	4 (25)	11 (34.4)		
≥ 4 serves per day	29 (30.2)	5 (31.3)	5 (31.3)	7 (43.8)	4 (25)	8 (25)		
Fruit consumption								
≤ 1 serve per day	45 (46.9)	7 (43.8)	9 (56.3)	9 (56.3)	8 (50)	12 (37.5)	2.56	0.63
2 serves per day	28 (29.2)	6 (37.5)	5 (31.3)	3 (18.8)	4 (25)	10 (31.3)		
≥ 3 serves per day	23 (24)	3 (18.8)	2 (12.5)	4 (25)	4 (25)	10 (31.3)		
Sugar sweetened beverage consumption								
Do not drink	34 (35.4)	3 (18.8)	6 (37.5)	4 (25)	9 (56.3)	12 (37.5)	6.02	0.2
< 1 cup per week	38 (39.6)	10 (62.5)	8 (50)	5 (31.3)	4 (25)	11 (34.4)		
1–3 cups per week	14 (14.6)	1 (6.3)	2 (12.5)	2 (12.5)	2 (12.5)	7 (21.9)		
≥ 4 cups per week	10 (10.4)	2 (12.5)	0 (0)	5 (31.3)	1 (6.3)	2 (6.3)		
Confectionary consumption								
< 1 time per week	18 (18.8)	3 (18.8)	4 (25)	3 (18.8)	3 (18.8)	5 (15.6)	1.11	0.9
1–2 times per week	38 (39.6)	7 (43.8)	6 (37.5)	8 (50)	5 (31.3)	12 (37.5)		
3–4 times per week	26 (27.1)	6 (37.5)	3 (18.8)	1 (6.3)	6 (37.5)	10 (31.3)		
≥ 5 times per week	14 (14.6)	0 (0)	3 (18.8)	4 (25)	2 (12.5)	5 (15.6)		

Note: [a] SE = standard error. Sex proportions tested using chi-squared tests. Food consumption variables tested using Kruskal-Wallis tests. All other variables tested with ANOVA.

Table 2
Mixed effects model results predicting DSC as a function of experiment and health warning group.

Predictor	*β (SE)*	*p*
Intercept	−26.01 (5.67)	< 0.0001***
Stage	0.51 (2.52)	0.84
Health Warning Condition		
Text-Positive	16.94 (9.23)	0.07
Text-Negative	−2.17 (9.21)	0.81
Graphic-Positive	4.09 (9.15)	0.65
Graphic-Negative	6.74 (9.19)	0.46
Stage x Health Warning Condition		
Text-Positive	−1 (4.51)	0.82
Text-Negative	11.08 (4.42)	0.01*
Graphic-Positive	10.83 (4.21)	0.01*
Graphic-Negative	23.35 (4.35)	< .0001***

Note: Health warning groups were dummy coded, with Control = 0. Stage was coded: unprimed = 0, primed = 1. * $p < 0.05$, *** $p < 0.0001$.

behaviors, some studies found support for positive frames (Pham, Mandel, & Morales, 2016), others showed the opposite (Nan et al., 2014) and others found a more complex picture whereby the relationship was moderated by another variable, such as self-efficacy (Mays et al., 2014). In light of these mixed results, some authors propose that health campaigns that employ a combination of the two may be more effective than using either alone (e.g. Mays et al., 2014; Pham et al., 2016). This approach is also supported by social theories of behavioral change (Strahan et al., 2002), which contend that behavioral change is driven by a combination of increasing perceptions of risk associated with the behavior of interest (which may be driven by negatively framed messages) and increasing self-efficacy about one's ability to change the behavior of interest (a potential target of positively framed messages). Future studies featuring exposure to a combination of positive and negative message frames may assist in testing this notion.

In addition to provoking the greatest improvement in dietary self-control, negatively framed graphic HWs produced this improvement through a combination of prompting participants to select healthier food items and suppressing the desire to select tasty food items (see additional analyses featured in Supplemental Materials). In contrast, the other effective health warning groups (graphic-positive and text-negative) were associated with an increased tendency to select healthy items only. These findings suggest that different HW formats could be employed to achieve different goals. For example, negatively framed graphic HWs, that also reduce an individual's desire to eat unhealthy energy-dense foods, may be more impactful in supporting population-level obesity prevention efforts than HWs that only increase preferences for healthier foods. However, industry may lobby against policy efforts to mandate such labels if they promote reduced consumption of certain products. In contexts where the use of HWs is voluntary rather than mandatory, a food company wishing to promote a new line of healthy snack food products may choose to display graphic-positive and text-negative HW messages, as they appear to uniquely encourage people to select healthier foods. Further exploration of these effects presents an exciting avenue for future research.

The present study overcomes some of the limitations of survey-based HW research (Ruiter & Kok, 2005) by measuring dietary choice behavior with a real, rather than hypothetical, outcome in an experimental setting. It must be acknowledged that the outcome measure used here is not directly equivalent to a 'real' dietary choice situation due to the probabilistic nature of the final outcome (participants did not obtain every item they expressed a preference for). This measure nonetheless allows for a greater degree of ecological validity than those of past research in this area. While it is not possible to completely remove the influence of social desirability in any study that involves

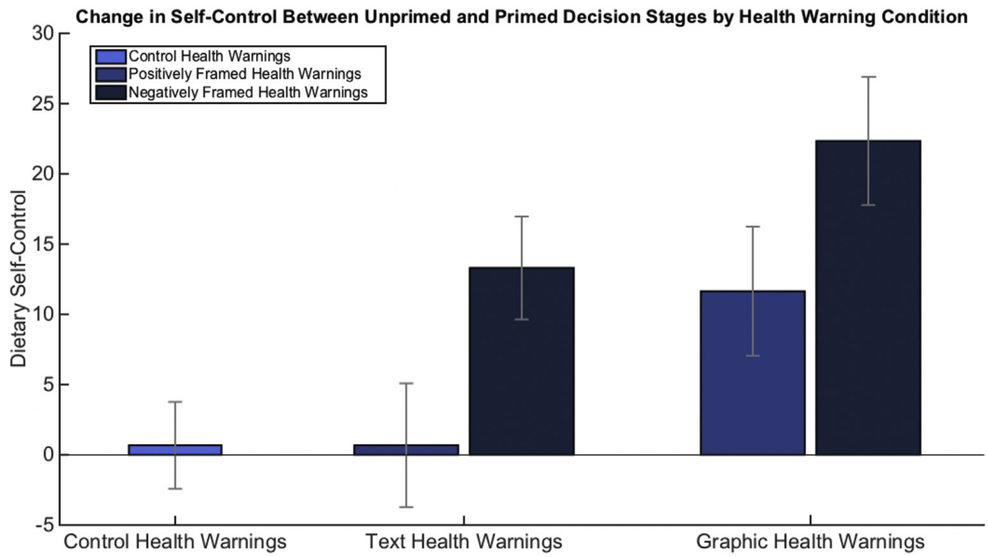

Fig. 3. Mean change in dietary self-control (measured as proportion of healthy-not tasty items chosen relative to unhealthy-tasty items chosen) between the unprimed and primed decision stages by health warning group. Error bars denote standard error.

presenting participants with health messages, by committing participants to the outcome of their decisions, it was possible to palliate social desirability biases and to investigate the ability of HWs to prime healthy eating 'in the moment'. Additionally, the outcome measure used in this study was likely less transparent to participants than self-report measures of purchase intentions, attitudes towards unhealthy food products, or perceived efficacy, as have been used in past studies in this area (Bollard et al., 2016; Roberto et al., 2016; VanEpps & Roberto, 2016). This is further supported by the differing degrees of change in dietary self-control observed for participants in each HW group; participants in all groups would be expected to display a similar degree of behavior change if demand effects were driving the observed results.

When interpreting the results, it is important to consider how the dietary choice procedure employed here might have influenced participant behavior. While some participants might have assumed that a "yes" response would be sufficient for a food item to be potentially made available for subsequent consumption, participants most likely assumed that the likelihood of receiving a particular food item was also affected by their response "strength". We observed changes in response strength across the entire scale and in both directions, supporting the notion that we successfully measured the strengths of their desire for consumption of each food item. However, it is important to note that capturing changes in the strength with which participants desire to eat or obtain the featured food items includes cases where participants still selected unhealthy items, but nonetheless showed a reduced desire to do so. The DSC values displayed by participants here were in part a function of the full set of snack foods featured in the study, as well as the subjective health and taste perceptions recorded by participants towards these foods. As a result of this, it is possible that an effect size that simply registers as a change in response strength (but not a change in food item chosen) in this brief simulated intervention may actually constitute a large enough effect to prompt a healthier choice in real-world decision contexts. However, these findings only provide a first indicator of shifts in decision strength in response to dietary health warnings. Further research is required to determine how the observed effects translate into altered food choice decisions in real-world settings (Wilson, Smyth, & MacLean, 2014). While no existing studies have specifically investigated the influence of product HWs on naturalistic dietary behavior, studies of prime-based interventions show promising results (Papies & Hamstra, 2010; Stöckli, Stämpfli, Messner, & Brunner, 2016), and the degree of behavioral change observed in our study is comparable to other prime-based dietary behavior interventions (Arno & Thomas, 2016).

There are other salient factors that may reduce the generalizability of these results. It remains unclear whether this pattern of results holds across populations with varying demographic characteristics such as socioeconomic status, age, education, race and ethnicity, as this experiment largely tested relatively young and educated Australian university students. This is of particular importance in light of the fact that the efficacy of certain text-based obesity prevention strategies, such as calorie labeling, is known to correlate with education (Breck, Cantor, Martinez, & Elbel, 2014), while graphic HWs are perceived as effective at similar rates across demographic groups (Cantrell et al., 2013). Nonetheless, the only study to explicitly test this in the context of text-only dietary HWs found that education did not influence recorded efficacy (Roberto et al., 2016). Furthermore, the sample used in this study was predominantly female. As women often display stronger health beliefs and are more likely than men to engage in healthy eating practices (Wardle et al., 2004) it is possible that this group displayed a greater priming effect than could be expected from a male only sample. Future research is required to investigate whether gender differences exist in this area.

Another important consideration regarding the generalizability of these results to different populations is the fact that the majority of our sample was of healthy weight. The epidemic prevalence of obesity and overweight in much of the world today (World Health Organization, 2000, pp. 1–252) indicates that these conditions have the potential to affect a broad segment of the population, and that effective preventive measures must similarly be shown to have broad effect. For this reason, we chose to investigate the efficacy of HW messages as a preventive measure in a sample that was not segregated by body weight status. Future studies could extend this research to assess responses to food product health warnings amount clinical populations.

Another detail potentially limiting generalizability to real world settings was the fact that participants in this study might have been exposed to HWs for longer than would be expected in a natural setting, as well as being explicitly encouraged to attend to them. While the present study investigated whether HWs were able to successfully prime healthier dietary choices when warnings were attended to, the extent to which individuals will pay attention to these warnings if they are introduced remains an open question. Research into nutrition labeling has found that many participants ignore nutrition labeling unless they are searching for specific information (Ares et al., 2013). Conversely, eye tracking studies investigating attention toward smoking warnings has found that they do capture the attention of at least certain populations (Maynard et al., 2014). This improved performance of tobacco HWs over nutritional information is possibly driven by differences between the size and location of these interventions, the visual and informational complexity, and other factors (Graham, Orquin, & Visschers, 2012). Consequently, the effectiveness reported here may be inflated, especially for text-based warnings, as they have been shown to be less readily attended to than graphic warnings (Hammond, 2011). Conversely, the exposure time featured here possibly better represents the influence of the frequent and repeated exposure that would be expected if food-product HWs were introduced. This exposure regime may therefore be more appropriate than that employed by certain other health messaging studies, which in some cases was brief (e.g. Pham et al., 2016) or employed a limited selection of messages (e.g. Effertz, Franke, & Teichert, 2013). This is an essential question for future research in this area to address, as no priming can be achieved if people simply ignore food product HWs.

Unlike survey-based studies, the paradigm used here did not assess the influence of HWs on beliefs and attitudes towards unhealthy dietary behavior, nor how such attitudinal change engenders intentions to improve dietary behavior. Nonetheless, it is possible that the introduction of HWs and other obesity prevention messages such as mass media campaigns may result in stronger priming effects than recorded here. As demonstrated in the tobacco control literature, increased exposure to HWs leads to greater knowledge of negative health outcomes, and greater intentions to alter behavior (Yong et al., 2014), thus strengthening latent health goals, which are subsequently primed at the next HW exposure. In this way, the ability of HWs to prime healthy eating may persist or even accumulate over time as other obesity prevention messages are introduced, though further research is required to test this idea.

This study contributes to a growing literature investigating the efficacy of HW labels as an obesity prevention strategy, and to our knowledge is the only controlled experimental study that has explicitly tested the ability of HWs to prime healthy dietary decisions as food choices are being made. One of the greatest advantages of HWs over other mass-media obesity prevention strategies is that they are a low-cost, high-reach intervention that can be presented to consumers as they engage in the relevant behavior. The results reported here corroborate findings from the tobacco control literature on the likely superiority of negatively framed graphic HWs and provide evidence for the efficacy of HWs as a component of population-level obesity prevention interventions.

Author contributions

D.R., S.B., C.M., M.W. and H.D. designed experiments. D.R., P.S. and A.N. ran experiments. D.R. conducted data analysis. All authors contributed to the interpretation of the results. D.R., S.B., C.M., M.W. and H.D. wrote the manuscript. All authors gave final approval for the submitted manuscript.

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Conflicts of interest

M.W. and H.D. currently work for organisations involved in public health research and advocacy. The other authors declared no conflicts of interest.

Availability of data and materials

Data and materials are available from the corresponding author on request.

Ethics approval and consent to participate

The University of Melbourne Human Research Ethics Committee approved all study procedures (reference number 1443258), and all participants provided written informed consent.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.appet.2018.05.006.

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