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Sim, Aaron Y.; Cheon, Bobby Kyungbeom

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Title: Influence of impending healthy food consumption on snacking:
Nudging vs. Compensatory behaviour

Authors: Aaron Y. Sim^{1,2}, Bobby K. Cheon^{1,2}

Affiliations: 1. Clinical Nutrition Research Centre (CNRC), Singapore Institute for Clinical
Sciences, Agency for Science, Technology and Research (A*STAR) and
National University Health System.

2. Division of Psychology, School of Social Sciences, Nanyang Technological
University, Singapore

Correspondence: Aaron Y. Sim

Singapore Institute for Clinical Sciences

Agency for Science, Technology and Research (A*STAR)

Address: Brenner Centre for Molecular Medicine, 30 Medical Drive, Singapore 117609

Telephone: +65 6407 4046

Fax: +61 6776 6840

Email: aaron_sim@sics.a-star.edu.sg

Abstract

The use of *nudging*, prompts or primes in the environment aligned with desired goals, as a strategy to promote healthy behaviour has gained increasing attention. Yet, the adoption of healthy behaviours may ironically be frustrated by licensing of competing goals for indulgence, producing compensatory unhealthy behaviours. However, little is known of these unintended compensatory effects of “health” *nudging*, and the conditions in which engagement of healthy behaviours may continue to activate health goals versus compensatory goals for indulgence. Over two studies, we examined both behavioural phenomena by investigating the influence of impending healthy food consumption on snack intake. We predicted that anticipated engagement of healthy eating will prime healthier eating behaviour (decreased snack intake), unless consumption of an anticipated healthy meal is expected to lead to an energy deficit (a “low calorie” meal), which may instead activate compensatory indulgence (increased snack intake). Study 1 demonstrated that the increase in the saliency of “healthiness” (unrelated to calorie content) from an anticipated meal resulted in lower snack intake (potato crisp consumption). Study 2 revealed that the anticipated consumption of a healthy meal described as low in caloric content promoted compensatory eating behaviour. This maladaptive behaviour was also observed to be associated with the endorsement of weight-regulation-related compensatory health beliefs. Furthermore, the findings also suggest that more restrained eaters (who experience competing goals for health and indulgence) may be especially likely to engage in healthier eating behaviour when anticipating healthy meals that were not portrayed to be low in calories. Taken together, our findings suggest that *nudging* by increasing the salience of healthy options without implying resulting negative energy balance is an effective strategy in promoting healthy eating behaviour and may be less prone to maladaptive compensatory behaviour, especially for individuals actively regulating their dietary behaviour.

Keywords: Priming, Compensatory health beliefs, Eating behaviour, Restrained eating

Introduction

The worldwide drive to address obesity (OECD, 2015), along with evidence attributing rising obesity rates to unhealthy eating behaviour (Prentice, 2001), has seen an increase in efforts to promote healthy eating. While specific methods and approaches may differ, a central theme of many of these healthy eating initiatives is to equip consumers with the necessary information to make better and healthier food choices. Examples of these include the “Health Star” rating (Australia, 2014) and “Healthier Choice” symbol (HPB, 1998) campaigns in Australia and Singapore respectively, where labels on packaging are used to indicate the “healthiness” of the food item.

Whether intended or not, these strategies to promote healthy eating behaviour rely substantially on a behavioural economic theory that has gained prominence in recent times – *nudging*. Formally introduced by Thaler and Sunstein (2014), *nudging* can be defined as slight changes to the environment that may influence people’s behaviour and choices in a manner that is unrestrictive of their (choice architecture) options and intended outcomes. Applied to the promotion of healthy eating, gentle prompts and suggestions that increase the saliency of “health” is proposed to increase consumers’ tendencies to adopt healthier eating behaviour. Indeed, a number of studies investigating the effects of *nudging* on eating behaviour appear to suggest that the use of goal-salient cues or primes in the environment (i.e. salience *nudges*) would result in goal-favourable outcomes, in this case, healthier food choices (Wilson et al., 2016). Accordingly, salience *nudges* have been suggested to influence behaviour by providing personally relevant and meaningful information to consumers to increase attention and elicit emotional associations to a particular goal or choice (Blumenthal-Barby and Burroughs, 2012). For instance, the use of traffic-light coloured labels on food products has been observed to elicit desired responses from consumers. Thorndik et al (2014) reported that sales of items labelled

green (i.e. healthy food) and red (i.e. unhealthy food) significantly increased and decreased respectively over a two year cafeteria based investigation. It is proposed that as traffic light colours have strong pre-established associations with motivational states (i.e. red means ‘stop’ and indicates “danger and poor health” while green means ‘proceed’ and indicates “safety and health”), consumers may automatically associate these meanings with the corresponding colour labelled foods (i.e. red labelled foods should be avoided and green labelled foods consumed). Similarly, the Singapore Health Promotion Board (HPB) reported approximately a 9% increase in sales per annum of food products with the “Healthier Choice” symbol since its introduction – Straits Times (2016). This ability to promote healthy behaviour via increased health salience of choice options has also been observed with the use of health associated word primes. Supermarket shoppers who were exposed to phrases like “good for your figure” and “healthy food” were observed to display healthier grocery shopping behaviour (i.e. reduced snack purchases) (Papies et al., 2014). Accordingly, it is suggested that labels that present health-aligned information or claims may prompt (*nudge*) emotional responses and behaviour that are in-line with consumers’ health goals, that is, display healthy eating behaviour (or decrease unhealthy eating behaviour). Notably, previous research in this area have largely only examined the influence of *nudging* on food choice (healthy vs. unhealthy choice) (Wilson et al., 2016). Investigations on the effects of *nudging* on actual caloric consumption (amount) may be required to provide a better insight to the magnitude of the influence of *nudging* on eating behaviour.

Interestingly, even amidst the increasingly widespread promotion of healthy eating and evidence suggesting its potential effectiveness, unhealthy eating habits (Prentice and Jebb, 2003, Rangan et al., 2008, Rangan et al., 2011) have remained or increased. While it should be acknowledged that determinants of an individual’s consumption patterns are multifactorial and complex, this continued prevalence of obesogenic eating behaviour suggest, at least in part,

that efforts to *nudge* or prime healthier eating habits may be limited in effectiveness or have possible counterproductive effects. The aim of this project was to explore the contexts in which impending or anticipated consumption of a healthy meal may *nudge* healthy eating in the present (reduced snack intake) or produce compensatory indulgence (increased snack intake).

The compensatory health belief model (CHB), provides a potential psychological framework that may help explain why even with the increase and widespread promotion of healthy eating, unhealthy consumption levels (and consequently overweight and obesity) have remained or increased. The CHB model proposes that when faced with temptations (e.g. snack food), individuals tend to form convictions that the negative consequences of current indulgent behaviour (e.g. consuming unhealthy calorie-dense foods) may be compensated for or “negated” by engaging in future positive healthy behaviour (Knäuper et al., 2004, Rabia et al., 2006). In support of this notion, findings from a recent study showed that when informed that they would be performing an upcoming bout of exercise (healthy behaviour), participants who had a tendency to monitor their food intake (restrained eaters), consumed more snacks compared with a no exercise, control condition (Sim et al., 2018). Intriguingly, this compensatory behaviour appears to take place even when exercise was not expected to be performed - the mere thought of exercise has been observed to increase snack consumption (Werle et al., 2011). Applied to the present research, while labels or cues of foods being ‘healthier’ may indeed increase their selection and consumption (Thorndik et al., 2014), expectations and anticipation of the consumption of such foods could potentially also serve as a license to indulge in unhealthy eating behaviour (i.e. increased snack intake). Yet, it remains unclear whether anticipated consumption of a “healthy” meal in the near future may similarly elicit compensatory indulgence in food intake, or if this pattern is limited to healthy behaviours associated with physical activity. Considering compensatory behaviour occurs when there is an expected resulting negative energy balance (i.e. energy expended from exercise as observed

in Sim et al, 2018), perceived ‘healthy’ eating may be especially likely to lead to compensatory behaviour (vs. *nudging* towards continued healthy behaviour) when it is perceived to lead to a deficit in one’s daily allowance of consumable calories (i.e., labelled as low or reduced calories).

Therefore, the main aim of the present research was to study the determinants of both behavioural phenomena (*nudging* vs compensatory health behaviour) by examining the influence of impending healthy food consumption on intake of a separate snack. We hypothesized that an increase in salience of “health” from the expectation of consuming healthy meal *without* implying a negative energy balance (e.g., low or reduced calories of the healthy meal) will result in healthy eating behaviour (i.e. decreasing snack intake) (Hypothesis 1). On the other hand, we predicted that the expectation of eating a healthy meal based on expectations that it will produce negative deficit or less positive energy balance will result in greater compensatory eating behaviour (i.e. increasing snack intake) (Hypothesis 2). Lastly, considering a) it has been previously shown that restrained eaters appear to be particularly sensitive to food-related environmental cues (Papies and Veling, 2013, Stämpfli et al., 2017) and maintain active yet competing goals for both healthy eating and indulgence and b) that the CHB framework has been proposed to explain maladaptive compensatory behaviour (Knäuper et al., 2004, Rabia et al., 2006), we hypothesised that the extent to which participants will be *nudged* or employ CHBs will be related to participants’ degree of dietary restraint (i.e. higher restraint more susceptible to either being *nudged* or CHBs) (Hypothesis 3a) and endorsement of CHBs (i.e. increase CHBs, more likely to compensate) (Hypothesis 3b) respectively.

Study 1

The purpose of study 1 was to investigate the influence of the impending consumption of a meal perceived to be “healthy” on prior snack consumption (Hypothesis 1). We expected that

participants would consume smaller portions of the *ad-libitum* test (snack) meal if it preceded a meal that was perceived to be “healthy”.

Methods

Participants

A total of 23 adults (10 men; 23 ± 3 years; BMI: $20.0 \pm 2.3 \text{ kg/m}^2$; body fat: $22.7 \pm 7.6\%$) were recruited from a Singaporean university. Sample size was determined based on previous research (Gregersen et al., 2008) that state 17 participants are required to detect the effect of differences in *ad-libitum* food intake (of 500 kJ or 120 kcal) from a within-subject design. Informed consent was obtained from all recruited participants with each compensated \$15 for completing the study. Only 20 participants' (8 men; 22 ± 3 years, BMI: $20.0 \pm 2.3 \text{ kg/m}^2$; body fat: $22.7 \pm 7.6\%$) data were included for analysis; two participants did not complete both sessions of the study, while one other participant was excluded due to consistently atypical responses and behaviour (e.g. “straight-lined” and extreme responses, “finished” dinner in about a minute). Ethics approval was granted by the university's internal review board (IRB).

Experimental design

This study used a randomized, counter-balanced within-subject design with two conditions – i) impending healthy food (IHF) condition and ii) impending conventional food (ICF) control condition (see Figure 1). The main difference between the conditions was the perceived healthiness of the *ad-libitum* dinner meal to be served at the end of each session. Dinner in the IHF condition was informed to be healthier than in the control condition when in actuality, the same foods were served in both conditions. The real objective of the study was not revealed until the end of the study. Instead, participants were informed that the study aimed to

investigate how typical daily activities (movie watching/studying) would affect the perception of a recently formulated trial food (served at dinner).

Experimental session

To complete the study, participants had to attend two experimental sessions (conditions randomly assigned) scheduled two weeks apart. Each session lasted approximately 4 hours and started at 1530h. The length of experimental session was to allow for the ecological assessment of snack (1545h) and dinner (1845h) consumption at typical periods of the day.

Pre-session. To standardised pre-experiment conditions, energy intake and expenditure influences that may potentially confound study outcomes were controlled for. Participants were requested i) to not perform any vigorous physical activity on the day prior to and on the day of a session and ii) to document and replicate (prior to the subsequent session) test day breakfast consumption. To increase the rate of compliance and decrease attrition rates, a reminder via email and/or instant messaging was provided prior to each session.

On the day of each session, participants were required to consume a standardized lunch, at approximately 1200h. The lunch comprised of a commercially prepared sandwich available from a food outlet conveniently located on campus (i.e. roasted chicken breast on multigrain bread with salad, Subway®, approximately 294 kcal). All participants reported that they fully consumed the provided lunch. Participants were also instructed not to consume any other food or drink between lunch and the start of the experimental session.

During the Session. Participants reported to the test venue at 1530h, where they registered, completed a baseline appetite ratings questionnaire (Visual Analog Scale; VAS. *Details in Food intake and appetite assessments section*) and briefed on the session's proceedings. They were told which condition they were assigned to for the session, that is, whether they would be

189 consuming the healthy version of the trial food (IHF) or the conventional version of the trial
190 food (ICF) at dinner - the trial food referred to “yang chow fried rice” (YCFR), a popular local
191 dish. In the IHF condition, participants were told that dinner was a recently formulated version
192 of YCFR that was i) healthier than (i.e. consumption resulted in improved post-prandial blood
193 glucose levels, assisted people in meeting daily recommended intake of vitamins and
194 antioxidants, and provided cardiovascular and musculoskeletal benefits), ii) as tasty and iii) as
195 filling as, conventional versions of the dish. These properties were specifically mentioned to
196 ensure that the study outcomes were influenced by the perceived “healthiness” of the trial food
197 rather than differences in taste and fillingness/perceived caloric content compared with control.
198 In the control condition, participants were informed that dinner comprised of YCFR that was
199 conventionally prepared (i.e what is typically sold at local food centres and restaurants). The
200 briefing was conducted by a study confederate that ostensibly played the role of a researcher
201 from the nutrition research lab that formulated the healthy trial food. A fabricated news article
202 (Appendix A), that included snippets of an interview with the research team regarding the trial
203 food, was also presented to further convince participants of the authenticity and validity of the
204 ‘newly formulated trial food’. A short survey following the briefing confirmed that participants
205 understood the properties of the trial food and differences between study conditions. Questions
206 regarding basic demographics and the consumption of the standardised lunch were included in
207 this questionnaire.

208 Next, participants were directed to spend approximately 100 minutes watching one of two
209 videos, romantic comedy movies ‘*The Proposal*’ and ‘*Friends with Benefits*’ - selected to
210 minimise any influence on eating behaviour that genres like horror have been reported to
211 induce (Tal et al., 2014, Mattar et al., 2015). During the movie, participants were provided *ad-*
212 *libitum* access to snack food (potato crisps) (*details in Food intake and appetite assessments*
213 *section*). Following this, participants had approximately 60 minutes of free time before dinner

was served. During this period, participants were encouraged to do school work and refrained from communicating with others. While this period was primarily used to standardize participant's behaviour and occupy and hold them until dinner, this activity also provided additional ecological influence on the study outcomes, that is, participants partook in activities they typically would. Finally, at 1830h, following a short briefing to remind participants which condition they were assigned to and what test food (IHF vs. ICF) was being served, participants were presented with dinner (details in Food intake and appetite assessments section). Participants then had their anthropometrical measures (height, weight and body composition; Tanita DC-360s Body Composition Analyser) assessed. Additionally, at the end of the second (final) session, participant's compensatory health beliefs (CHB) composite (Cronbach α = 0.76) (11.8 ± 1.7), CHB *Substance use* subscale (Cronbach α = 0.74) (13.0 ± 3.7), CHB *Eating/Sleeping* subscale (Cronbach α = 0.66) (11.3 ± 3.2), CHB *Stress* subscale (Cronbach α = 0.63) (14.8 ± 2.4), CHB *Weight regulation* subscale (Cronbach α = 0.57) (8.2 ± 1.7) (Knäuper et al., 2004), and attitudes towards eating (Three Factor Eating Questionnaire; TFEQ) (de Lauzon et al., 2004), TFEQ dietary restraint subscale (Cronbach α = 0.76) (2.0 ± 0.6), TFEQ uncontrolled eating subscale (Cronbach α = 0.83) (2.5 ± 0.5), TFEQ emotional eating subscale (Cronbach α = 0.85) (2.1 ± 0.6) were also assessed. Briefings were done as a group, while video-watching and food consumption was done individually and privately (own cubicle, computer, dining space).

Post-session. Participants were required to document any food or drink consumption that followed dinner (i.e. supper). Following the last experimental session, participants were debriefed and provided information regarding the true aim of the study.

238 *Food intake and appetite assessments*

239 Energy intake was assessed at various points of the experiment to study the influence of the
240 experimental protocols/manipulation on eating behaviour. Pre- and post-experimental session,
241 free-living energy intake was assessed by requesting participants to document all food and
242 drink consumption via an online survey system (Qualtrics®, United States). An estimate of the
243 energy consumed prior to and after the experimental session was determined using
244 commercially available dietary assessment software (Foodworks; Xyris Software, Queensland,
245 Australia).

246 Snack intake was made available for a fixed duration of 100 min during the movie screening
247 (for both IHF and ICF) and consisted of non-restricted access to commercially available potato-
248 crisps (Original Flavoured Potato-Chips, First Choice, Cold Storage, Singapore) of known
249 quantity and nutrition content (portion presented was equivalent to two full bags of crisps; 1163
250 kcal). The potato crisp was also presented together with 250 ml of bottled plain water.
251 Participants were informed they could have more potato crisps and water than what was
252 initially provided. Experimenters were also vigilant in monitoring (covertly) how much snack
253 and drink was available to participants - participants were automatically served an additional
254 bowl of potato crisps or bottled water if they were seen finishing what they were provided (two
255 participants finished their original bowl of crisps). The potato crisps were weighed, out of
256 participants' sight, before and after consumption.

257 Dinner in the form of YCFR, presented buffet-style in food warmers, was self-served and
258 consumed privately (i.e. not in the presence of others). Similar to the potato-crisps served
259 earlier in the session, dinner was provided ad-libitum and participants were told they could
260 have as much food as they would like (i.e. that they could have several helpings). Participants
261 were also asked questions (using a 100 point VAS) regarding how much they liked (65 ± 14),

how tasty they thought (62 ± 15) and how often they consumed (49 ± 23) the potato crisps'. The YCFR served for both conditions was commercially prepared by the same catering company and similar in caloric content (160 ± 6 kcal/100g, $P=0.261$) across the two sessions. The caloric content of the fried rice was determined using a commercially available near-infrared calorie-analysis device (*Calorie Answer*, Joy World Pacific, Aomori, Japan) (Lau et al., 2016). Similar to the assessment of the amount of snack consumed, the amount of dinner consumed was calculated by subtracting the amount of YCFR left on the plate by the total amount self-served. Participants also completed a number of questions regarding the dinner's perceived healthiness, tastiness, fillingness and ability to satisfy.

Perceived appetite in the form of ratings of hunger, fullness, satiety, desire to eat, and prospective food consumption ("How much do you think you could eat?") was periodically assessed at four time-points i) at the start of the session (baseline), ii) post-snack (after the movie), iii) pre-dinner (after the free-time), and iv) post-dinner (at the end of the session).

Study 1 Results

Experimental Session Characteristics

Pre-experiment energy intake from breakfast and lunch were well matched across sessions (energy intake: IHF 460 ± 163 kcal, ICF 479 ± 222 kcal; $F(1,17)=0.199$, $p=0.661$ $\eta_p^2 = 0.012$). No differences in baseline appetite (hunger $t(19)=-0.204$ $p=0.840$, fullness $t(19)=-0.56$ $p=0.585$, satiety $t(19)=-0.60$ $p=0.559$, desire to eat $t(19)=-0.55$ $p=0.591$ and prospective food consumption $t(19)=0.28$ $p=0.782$) between experimental conditions were observed.

Manipulation Check

To assess participant's opinions of the dinners served in the IHF and ICF conditions, questions regarding the healthiness, amount of calories, taste and how filling the YCFR was were presented following dinner. As expected, participants felt the YCFR in the IHF condition was healthier, $F(1,19)=15.050$, $p=0.001$ $\eta_p^2=0.442$, and contained less calories, $F(1,19)=4.142$, $p=0.056$ $\eta_p^2=0.179$, compared with ICF. Interestingly, participants also felt that the IHF dinner was tastier, $F(1,19)=6.331$, $p=0.021$ $\eta_p^2=0.250$, and more filling, $F(1,19)=6.708$, $p=0.018$ $\eta_p^2=0.261$ (Table 1).

Trial Session Energy Intake (Ad-libitum)

Snack Intake

A repeated-measures analysis of variance (ANOVA) was conducted to determine the influence of the IHF condition on snack and dinner intake. In support of Hypothesis 1, we found that participants consumed less potato crisps in IHF compared with ICF, $F(1,19) = 4.392$, $p=0.050$ $\eta_p^2=0.188$ (Figure 2). Considering i) participants' levels of appetite may differ and ii) anthropometrical characteristics have been shown to be significantly associated with individual energy requirements (i.e. basal metabolic rate) (Henry, 2005), we further analysed snack intake, whilst controlling for participant's composite baseline hunger and BMI. This revealed an even stronger main effect of condition, $F(1,17)=7.082$, $p=0.016$ $\eta_p^2=0.294$, demonstrating reduced snack intake in IHF compared with ICF, Figure 2. Critically, no order effect of snack intake (1st vs 2nd test session) (i.e. comparing snack intake between conditions while controlling for experimental order) was detected, $F(1, 18)=0.093$, $p=0.764$. There were also no differences in water intake between conditions during snack intake $F(1,19)=2.029$, $p=0.171$ $\eta_p^2=0.096$.

Dietary restraint was significantly associated with the difference in snack intake between conditions (snack intake in IHF minus ICF) ($r(16)=-0.500$, $p=0.034$, controlling for baseline composite hunger and BMI), such that as participants exhibited greater dietary restraint, they consumed smaller amounts of crisps in the IHF condition compared to the ICF condition (Figure 3).¹

Dinner Intake

Repeated measures ANOVA revealed no difference in dinner intake between conditions, $F(1,19)=0.003$, $p=0.957$ $\eta_p^2=0.000$. This indifference remained even after accounting for participants' BMI and hunger, $F(1,17)=0.152$, $p=0.701$ $\eta_p^2=0.009$. While an order effect was detected for dinner intake ($F(1,19)=5.753$, $p=0.027$ $\eta_p^2=0.232$; participants ate more in the second session), controlling the analysis for order did not reveal any difference in dinner intake between condition, $F(1,17)=1.142$, $p=0.300$ $\eta_p^2=0.063$. Importantly, no difference in dinner intake was observed while controlling for the amount of snack consumed prior to dinner, $F(1,18)=0.354$, $p=0.559$ $\eta_p^2=0.019$. There was also no differences in water intake between conditions during dinner, $F(1,19)=0.015$, $p=0.903$ $\eta_p^2=0.001$.

Free-Living Energy Intake

Post-Dinner Intake

Only 9 (out of 20) individuals ate post-dinner. While there were no statistically significant differences in food consumed subsequent to dinner between conditions ($F(1,8)=1.788$, $p=0.218$

¹ Additional outcomes of analyses examining associations between snack intake and other assessed psychological measures can be found in the *Supplementary Materials* document.

325 $\eta_p^2=0.294$, energy intake tended to be lower in IHF (72 ± 83 kcal) compared with CON
326 (143 ± 136 kcal).

327 ***Perceptions of Appetite***

328 There were no differences in perceived appetite ratings between experimental conditions at the
329 various time-points throughout the whole experimental session; *post-movie* (hunger $t(19)=1.41$
330 $p=0.174$), fullness $t(19)=1.23$ $p=0.233$, satiety $t(19)=0.87$ $p=0.395$, desire to eat $t(19)=1.70$ p
331 $P=0.106$ and prospective food consumption $t(19)=1.07$ $p=0.299$), *pre-dinner* (hunger
332 $t(19)=0.20$ $p=0.841$, fullness $t(19)=1.00$ $p=0.328$), satiety $t(19)=0.45$ $p=0.657$, desire to eat
333 $t(19)=-0.28$ $p=0.781$ and prospective food consumption $t(19)=1.15$ $p=0.264$), *post-dinner*
334 (hunger $t(19)=-1.64$ $p=0.117$, fullness $t(19)=-1.18$ $p=0.252$, satiety $t(19)=-1.28$ $p=0.215$, desire
335 to eat $t(19)=-1.45$ $p=0.163$) and prospective food consumption $t(19)=-1.16$ $p=0.261$).

336 **Study 1 Discussion**

337 Study 1's findings demonstrate that the expectation of consuming healthy food without
338 implying a resulting deficit to energy balance may have primed or activated goals for healthier
339 or less indulgent eating behavior (salience "*nudging*"), in this case, decreased snack intake
340 (supporting Hypothesis 1). Participants who reported higher levels of dietary restraint also
341 displayed increased susceptibility to being "*nudged*" (supporting Hypothesis 3a), likely due to
342 heightened accessibility of healthy eating goals among this group. Yet one limitation of Study
343 1 was the lack of a situation in which participants expected to consume an impending healthy
344 meal based on low calories (perceived deficit to energy balance) (test of Hypothesis 2), which
345 was introduced in Study 2.

346

347

Study 2

The main aim of this follow-up study was to determine whether eating behaviour (healthy vs. unhealthy) in response to the anticipated consumption of a healthy meal, may be dependent on the outcome of the up-coming behaviour as being perceived to produce a deficit in subsequent energy balance. Another key difference between Study 1 and 2 is that eating behaviour outcomes in Study 2 were assessed by examining portion selection patterns. Prior research (Forde et al., 2015) have demonstrated that portion sizes selected on the computer-based portion selection task is a reliable alternative for actual food intake assessment. Another reason for using this approach was to address the limitation of the assessment of eating behaviour based on only one snack item (Study 1) – the use of the portion selection approach allowed for the examination of intended energy intake behaviour to a diverse array of snack items.

Study 2 Methods

Participants

One hundred and forty-two participants (56 men; 21.7 ± 2.0 years; BMI $21.7 \pm 3.1 \text{ kg/m}^2$) were recruited for this study from a Singaporean university community. A sample-size of 158 was estimated to be required based on an alpha level of 0.05, power of 0.80 and an effect size target of 0.25 (medium; based on Cohen's guidelines for f value) – calculated using G*Power 3 (Cohen, 1969, Faul et al., 2007). All participants gave written consent and were compensated \$5 for completing the study, which was approved by the university's IRB.

367 *Procedure and Materials*

368 Participants, who were not privy to differences in procedures associated with each experimental
369 condition/session, randomly signed up to participate in one of three experimental groups: the
370 expectation of a hypothetical dinner meal, “yang chow fried rice” (YCFR), of i) healthy
371 properties (HP) (n=43) ii) lower calories (LC) (n=48) or conventional properties (n=51)
372 (control; CON) condition. A between-subjects design was implemented for this study to
373 prevent a “carry over” effect of experimental conditions (especially of HP and LC) to key study
374 outcomes. The experimental procedure was largely similar for all three experimental conditions
375 except for the manipulation employed. Participants completed the baseline measure of appetite
376 ratings used in Study 1, before being briefed on the session’s proceedings. Participants were
377 told they were part of a series of “field tests” that hope to understand the opinions and
378 judgements of consumers of a newly formulated trial food and told to imagine a hypothetical
379 scenario where they would be asked to consume a mid-afternoon snack prior to either a healthy
380 trial food (HP or LC) or conventional (CON) meal for dinner. Experimental sessions were
381 conducted during periods of the day where snacking would typically occur (1430 to 1700hr).
382 In HP, this healthy meal was described as a newly created version of a conventional food item
383 that provides the same caloric content as the conventional version, but with significantly
384 enhanced health properties. In LC, the healthy dinner meal was described as being significantly
385 lower in calories compared with conventional versions of the food item, whilst retaining the
386 same taste and satisfaction. In CON, the dinner meal was described as being of a conventional
387 version of the food item typically served. Participants were then told that they would be
388 required to complete a number of questionnaires and a computerised portion selection task
389 (PST) to assess the intended portion of potential afternoon snacks they would consume given
390 the anticipated hypothetical dinner (HP or LC) they would consume later (described in more
391 detail below).

Following the briefing, to allow participants to better understand the distinctive features (i.e. healthy similar calories vs. lower calories) of the hypothetical anticipated meal, participants were presented with a fabricated article that described the upcoming meal. Sample text from the HP condition article included, “*created a whole range of local foods that were many times healthier without compromising on taste, flavour and ability to fill consumers up,*” While the LC condition article included, “*created a whole range of local foods that were many times lower in calories without compromising on taste, flavour and consumer satisfaction.*” After reading the respective fabricated articles (HP vs. LC), participants completed a quiz about the article to reinforce the distinct characteristics of the upcoming meal (e.g. “*The researchers have created new versions of local foods that are much healthier*” “*The researchers have created new versions of local foods that have significantly lower caloric content*”). Participants’ understanding of the expected hypothetical meal were confirmed by their responses to the questions (*nb:* all participants’ responses were as expected).

Following the manipulation, participants completed the computerized PST. The PST is based on previous validated versions of computerized assessments of portion selection and intended food consumption (Brunstrom et al., 2008, Brunstrom and Rogers, 2009, Wilkinson et al., 2012). The modified PST program for the present study involved the display of high-resolution images of ten different snack food items (e.g. potato crisps, french fries, chicken nuggets, chocolate cake, Maltesers) served on the same dinner plate with user-controlled portion sizes, presented in a randomized order. For each item, participants could dynamically increase or decrease the portion size displayed in equicaloric steps ranging from 20 to 1000 kcals in 20 kcal increments by pressing the right or left arrows on the computer keyboard (see Figure 4). Participants were required to select the portion of each food item from the series of food portion images that they thought best represented the amount they would like to served themselves and

consume for their next snack (*“Please select the amount of food that you like to eat for your next snack?”*).

After participants finished the PST, they answered (similar to Study 1) questions regarding their compensatory health beliefs (composite 11.8 ± 2.3 , *Substance use* subscale 13.0 ± 3.7 , *Eating/Sleeping* subscale 11.3 ± 3.2 , *Stress* subscale 14.8 ± 2.4 , *Weight regulation* subscale 14.8 ± 2.4) and attitudes towards eating (TFEQ) (de Lauzon et al., 2004) (dietary restraint 2.4 ± 0.6 , uncontrolled eating 2.5 ± 0.6 , emotional eating 2.3 ± 0.8), and had their anthropometrical measures (height, weight and body composition; Tanita DC-360s Body Composition Analyser) assessed.

Study 2 Results

Snack Food Portion-selection

An analysis of variance (ANOVA), revealed no main effect of experimental condition on the amount of snack food (calories) selected on the PST, $F(2,139)=2.010$, $p=0.138$ $\eta_p^2=0.028$. Importantly, an analysis of covariance (ANCOVA), controlling for baseline hunger and BMI (as per Study 1) revealed a significant difference in the amount of snack food (calories) selected on the PST between the experimental conditions, $F(2,137)=3.646$, $p=0.029$ $\eta_p^2=0.051$. Supporting Hypothesis 2, post-hoc analyses showed that participants on average selected significantly larger amounts of snack food on the PST in LC compared with CON, ($p=0.036$; Figure 5). No other significant comparisons were observed of PST ratings between the other experimental conditions; (HP vs. LP $p>0.999$; HP vs CON $p=0.140$; Figure 5).

Dietary restraint scores were negatively correlated with PST snack portion selection in HP $r(39)=-0.322$ $p=0.040$ and CON $r(46)=-.410$, $p=0.010$ (controlling for hunger and BMI; Figure 6). Notably, this relationship was not observed in LC $r(44)=-0.153$, $p=0.311$. Instead, CHB

Weight-Regulation subscale scores were positively correlated with the portion of snack food selected on the PST only in LC $r(44)=-.296$ $p=0.046$ and not HP $r(39)=-.225$ $p=0.158$ and CON $r(46)=-.137$ $p=0.354$ (controlling for hunger and BMI; Figure 7).²

Study 2 Discussion

Findings from Study 2 provide support that compensatory unhealthy (vs. *nudged* healthy) eating behaviour responses may be more likely when upcoming health-promoting behaviours are perceived to influence (produce a deficit in) subsequent energy balance (Hypothesis 2). In line with Hypothesis 3b, participants in LC who endorsed CHBs (in particular CHBs associated with weight regulation) displayed increased tendencies to adopt maladaptive compensatory eating behaviour.

While we did not observe direct support for the ability of anticipated healthy behaviour to prime (*nudge*) healthy eating behaviour (Hypothesis 1), this may be a result of the between-subjects design of the study. That is, due to potentially different “baseline” portion-selection sizes of the experimental groups, the outcome of participants in HP being “*nudged*” may not have been as apparent. Importantly, this explanation is supported by the negative association observed between dietary restraint and snack food portion selection patterns in HP (and not in LC) – an association similarly observed in Study 1 (supporting Hypothesis 3a).

General Discussion

The present research’s main objective was to examine psychological mechanisms that may potentially modulate the influence of impending healthy behavior (eating an upcoming ‘healthy’ meal) on unhealthy eating behaviour, in particular, snacking on energy-dense foods. In support of our hypotheses, the present research suggests an overall ability of expectations of

^{2 2} Additional outcomes of analyses examining associations between snack intake and other assessed psychological measures can be found in the *Supplementary Materials* document.

upcoming meal events to have an influence on more immediate eating behaviour. Specifically, the findings demonstrate i) that the anticipated consumption of a healthy meal primes (i.e. provides a healthy “salience” *nudge* to) individuals to adopt healthier behaviour in another eating situation, in this case, decreased snack intake (Hypothesis 1) and ii) that the expected consumption of a meal labelled ‘healthy’ due to low calories promoted compensatory maladaptive eating behaviour (i.e. increased snack food selection) (Hypothesis 2). Finally, we also found support for inter-individual variation in the present research’s key outcomes. We observed tendencies i) of being nudged to display healthy snacking behaviour and ii) of employing CHBs that result in more indulgent snacking behaviour, to be more pronounced among individuals i) with higher dietary restraint (Hypothesis 3a) and ii) who endorsed weight regulation-related CHBs (Hypothesis 3b) respectively.

The experimental design of the present research (Study 1) allowed for the novel examination of the influence of anticipated healthy meals on the actual amount of calories consumed (as opposed to binary healthy vs. unhealthy food selection outcomes) on both the food items the health prime was directly applied to (i.e. the dinner meal) and an incidental snack consumed prior (i.e. the potato crisps). Consistent with evidence demonstrating the ability of healthy reminders and descriptions of food and beverage items to elicit healthy responses from consumers (Levy et al., 2012, Schwartz et al., 2012, Papies and Veling, 2013, Thorndike et al., 2014, Papies, 2016), we observed that informing individuals that they were going to be consuming a healthy meal resulted in healthier eating behaviour (decrease potato crisp intake) on a separate eating event, suggesting the activation of a more generalized healthy eating goal. Impending or anticipated consumption of healthy food may potentially activate or “*nudge*” such healthy eating goals through increasing the salience of a healthy eating goal, or through self-perception mechanisms (Bem, 1972) that promote an impression of oneself as being someone who engages in healthy eating (e.g., impending healthy dinner meal) and motivates

consistency of subsequent behaviors with this impression (e.g., reduced snack intake). Of interest, in Study 1, there was no difference in the amount of dinner consumed between the two experimental conditions (IHF vs. CON). Considering “expected satiation” (i.e. expectations of the fullness a food is expected to deliver) has previously been shown to be an accurate predictor of food intake (Wilkinson et al., 2012, Forde et al., 2015), one possibility for this lack of difference may be due to the dinner meal in IHF being described as being as filling as the meal presented in the CON condition (E.g. “... without compromising on taste, flavour and ability to fill consumers up ...”). It should be noted that while the within-subject design of Study 1 presents potential confounding “carry-over” influence on dinner intake, this was not apparent considering the similar dinner intake between conditions.

One of the key aims of the present research was to study contextual factors that determine whether engagement or consumption of healthy behaviours/products consequently leads to health-congruent behaviour (*nudging*) or compensatory indulgence. Consistent with previous research demonstrating how an individual’s caloric consumption limits may be influenced by personal daily calorie budgets (Oh et al., 2016), we predicted that healthy eating behaviour emerging from consumption of foods perceived to be ‘healthy’, may occur only when resultant energy balance was perceived to be unaffected. In support of this line of reasoning, when upcoming behaviour was perceived to result in negative energy balance (i.e. consuming lower calories), an increase in intended unhealthy snack intake (suggesting license to indulge) was evident in our observations (Study 2). This finding is consistent with previous findings that demonstrated that expectations of upcoming exercise (an opportunity to expend energy and influence energy balance) (Sim et al., 2018) or a period of fasting (Eldredge et al., 1994) resulted in an increase in snack consumption in individuals that monitor their food intake. Vitally, taken together, these findings demonstrate that efforts to ‘*nudge*’ consumers towards healthier diets by labelling foods as ‘healthy’ may have more beneficial and less compensation-

prone outcomes on overall dietary behaviour if portrayals of the ‘healthiness’ of foods is based on properties unrelated to low calories.

Nonetheless, it should be noted that in Study 2, no differences in snacking behaviour were observed between participants that were told to anticipate the consumption of a healthy food (not labelled as low in calories; HP) versus the consumption of the conventional version of the food (CON) – a lack of a *nudging* effect. As discussed earlier, this may likely be a result of the between-subjects design of the study. Yet, similar to Study 1, we also observed a significant negative correlation between participant’s dietary restraint and snack food portion selection patterns in HP. These findings have important implications considering restrained eaters have previously been shown to be unsuccessful with dieting because of their vulnerability to obesogenic environmental cues (Stämpfli et al., 2017). Finally, the present research (Study 2) provides initial support for the notion that people with the tendency to endorse CHBs, in particular ones related to weight-regulation, are more susceptible to adopt maladaptive compensatory eating behaviour. This is an important insight, especially for the management of overweight and obesity, given that prior research have demonstrated that intended healthy compensatory behaviour may not be enough to “negate” unhealthy behaviour (Sim et al., 2018) and even if effective, these healthy behaviour are often not carried out. Future research is needed to examine the relationships presented above, specifically with regard to the mediating influence, dietary restraint and CHBs, may exert on eating behaviour in response to the anticipated consumption of a healthy meal.

One limitation is that our findings on snack intake in Study 1 were restricted to a single snack item and the type of test-meal used. Nonetheless, it should be noted that participant ratings of the potato crisps indicate its appropriateness as an appropriate test food item: the potato crisps were rated mildly palatable, moderately liked, and not consumed too frequently or infrequently (see results in Study 1’s Food intake and appetite assessments). This limitation was partially

536 addressed in Study 2 by using a composite of portion selection responses from an array of
537 snack food to assess eating behaviour.

538 In conclusion, the present research's main findings suggest that reminders of healthy
539 behaviours, without implying of negative energy balance, may be a viable approach to promote
540 healthy eating behaviour, especially among those who struggle to override their desires to
541 indulgence with goals for healthy eating.

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548 **Conflict of interest**

549 The authors declare no conflict of interest.

550 **References**

- 551 *Australia, C. o. (2014). Health Star Rating System.*
- 552 *Bem, D. J. (1972). "Self-perception theory." Advances in experimental social psychology 6: 1-*
553 *62.*
- 554 *Blumenthal-Barby, J. S. and H. Burroughs (2012). "Seeking better health care outcomes: the*
555 *ethics of using the "nudge". The American Journal of Bioethics 12(2): 1-10.*
- 556 *Brunstrom, J. M. and P. J. Rogers (2009). "How Many Calories Are on Our Plate? Expected*
557 *Fullness, Not Liking, Determines Meal-size Selection." Obesity 17(10): 1884-1890.*
- 558 *Brunstrom, J. M., et al. (2008). "Measuring 'expected satiety' in a range of common foods using*
559 *a method of constant stimuli." Appetite 51(3): 604-614.*
- 560 *Cohen, P. J. (1969). "Decision procedures for real and p-adic fields." Communications on*
561 *Pure and Applied Mathematics* 22(2): 131-151.
- 562 *de Lauzon, B., et al. (2004). "The Three-Factor Eating Questionnaire-R18 is able to distinguish*
563 *among different eating patterns in a general population." J Nutr 134(9): 2372-2380.*
- 564 *Eldredge, K. L., et al. (1994). "The last supper: emotional determinants of pretreatment weight*
565 *fluctuation in obese binge eaters." International Journal of Eating Disorders 16(1): 83-88.*
- 566 *Faul, F., et al. (2007). "G*Power 3: A flexible statistical power analysis program for the social,*
567 *behavioral, and biomedical sciences." Behavior Research Methods 39(2): 175-191.*
- 568 *Forde, C. G., et al. (2015). "Expected Satiety: Application to Weight Management and*
569 *Understanding Energy Selection in Humans." Current Obesity Reports 4(1): 131-140.*
- 570 *HPB (1998). Healthier Choice Symbol.*

571 Knäuper, B., et al. (2004). "Compensatory health beliefs: scale development and psychometric
572 properties." Psychology & Health **19**(5): 607-624.

573 Lau, E., et al. (2016). "Rapid estimation of the energy content of composite foods: the
574 application of the Calorie Answer(TM)." Asia Pacific Journal of Clinical Nutrition **25**(1): 18-
575 25.

576 Levy, D. E., et al. (2012). "Food choices of minority and low-income employees: a cafeteria
577 intervention." Am J Prev Med **43**(3): 240-248.

578 Mattar, L., et al. (2015). "Effect of movie violence on mood, stress, appetite perception and
579 food preferences in a random population." Eur J Clin Nutr **69**(8): 972-973.

580 OECD (2015). Health at a Glance 2015: OECD Indicators, OECD Publishers, Paris.

581 Oh, G.-E. G., et al. (2016). "The Mental Budgeting of Calories: How Nutrition Information
582 Influences Food Consumption Day By Day, Not Meal By Meal." ACR North American
583 Advances.

584 Papies, E. K. (2016). "Health goal priming as a situated intervention tool: how to benefit from
585 nonconscious motivational routes to health behaviour." Health Psychol Rev **10**(4): 408-424.

586 Papies, E. K., et al. (2014). "Using health primes to reduce unhealthy snack purchases among
587 overweight consumers in a grocery store." Int J Obes (Lond) **38**(4): 597-602.

588 Papies, E. K. and H. Veling (2013). "Healthy dining. Subtle diet reminders at the point of
589 purchase increase low-calorie food choices among both chronic and current dieters." Appetite
590 **61**: 1-7.

591 Prentice, A. M. (2001). "Overeating: the health risks." Obes Res **9 Suppl 4**: 234s-238s.

592 Prentice, A. M. and S. A. Jebb (2003). "Fast foods, energy density and obesity: a possible
593 mechanistic link." *Obesity reviews* **4**(4): 187-194.

594 Rabia, M., et al. (2006). "The eternal quest for optimal balance between maximizing pleasure
595 and minimizing harm: The compensatory health beliefs model." *British Journal of Health*
596 *Psychology* **11**(1): 139-153.

597 Rangan, A. M., et al. (2011). "Changes in 'extra'food intake among Australian children
598 between 1995 and 2007." *Obesity research & clinical practice* **5**(1): e55-e63.

599 Rangan, A. M., et al. (2008). "Consumption of 'extra'foods by Australian children: types,
600 quantities and contribution to energy and nutrient intakes." *European journal of clinical*
601 *nutrition* **62**(3): 356.

602 Schwartz, J., et al. (2012). "Inviting consumers to downsize fast-food portions significantly
603 reduces calorie consumption." *Health Aff (Millwood)* **31**(2): 399-407.

604 Sim, A. Y., et al. (2018). "When exercise does not pay: Counterproductive effects of impending
605 exercise on energy intake among restrained eaters." *Appetite* **123**: 120-127.

606 Stämpfli, A. E., et al. (2017). "A nudge in a healthier direction: How environmental cues help
607 restrained eaters pursue their weight-control goal." *Appetite* **110**: 94-102.

608 Tal, A., et al. (2014). "Watch what you eat: Action-related television content increases food
609 intake." *JAMA Internal Medicine* **174**(11): 1842-1843.

610 Thaler, R. H., et al. (2014). "Choice architecture."

611 Thorndike, A. N., et al. (2014). "Traffic-Light Labels and Choice Architecture Promoting
612 Healthy Food Choices." *American journal of preventive medicine* **46**(2): 143-149.

613 Thorndike, A. N., et al. (2014). "Traffic-light labels and choice architecture: promoting healthy
614 food choices." American journal of preventive medicine **46**(2): 143-149.

615 Times, S. (2016). Healthier-choice food products getting popular, *Straits Times*.

616 Werle, C. O., et al. (2011). "Just thinking about exercise makes me serve more food. Physical
617 activity and calorie compensation." Appetite **56**(2): 332-335.

618 Wilkinson, L. L., et al. (2012). "Computer-based assessments of expected satiety predict
619 behavioural measures of portion-size selection and food intake." Appetite **59**(3): 933-938.

620 Wilson, A. L., et al. (2016). "Nudging healthier food and beverage choices through salience
621 and priming. Evidence from a systematic review." Food Quality and Preference **51**: 47-64.

622

Figures

Figure 1 - Study 1 Experimental flowchart reflecting protocol before, during and after the experimental session.

Figure 2 – Study 1: Mean ($\pm$ SE) energy intake at the test-snack meal (potato-crisps) during the impending healthy food (IHF) and impending conventional food (ICF) experimental conditions. ($n = 20$). #Significantly different from ICF (controlling for hunger and BMI). ($P = 0.017$).

Figure 3 – Study 1: Correlation of the difference in snack intake between experimental conditions (IHF vs. ICF) and dietary restraint scores ($r=-0.482$, $P=0.037$) (controlling for hunger and BMI) ($n = 20$)

Figure 4 –Study 2: Example of snack food portion-size images (presented individually) displayed on the portion selection computer program. Keyboard commands to increase (right arrow key) or decrease (left arrow key) food portion images correspondingly changed the portion size of displayed by the image in 20 kcal increments ranging from 20 to 1000 kcal (50 images total per food).

Figure 5 – Study 2: Mean ($\pm$ SE) amount (kcal) of snack food selected on a computerised portion selection task during the hypothetical upcoming meal of Healthy Properties (HP) ($n=43$), Lower Calories (LC) ($n=48$) and Conventional (control; CON) ($n=51$) experimental conditions. [#]Significantly different from CON (controlling for hunger and BMI). ($P = 0.036$).

Figure 6 – Study 2: Correlation of the mean amount (kcal) of snack food selected on a computerised portion selection task and dietary restraint scores in the Healthy Properties (HP) experimental condition ($r=-0.322$, $p=0.040$) (controlling for hunger and BMI) ($n = 43$)

Figure 7 – Study 2: Correlation of the mean amount (kcal) of snack food selected on a computerised portion selection task and CHB Weight Regulation subscale scores in the Lower Calories (LC) experimental condition ($r=0.296$, $p=0.046$) (controlling for hunger and BMI) ($n = 48$).

711 *Table 1 – Study 1: Means and standard deviations of dinner food ratings between*
 712 *experimental conditions - impending healthy food (IHF) and impending conventional food*
 713 *(ICF). [#]Significantly different from ICF ($P \leq 0.050$) ($n=20$).*

	IHF		ICF	
	<i>Mean</i>	<i>Std. Dev</i>	<i>Mean</i>	<i>Std. Dev</i>
Tasty	70.7 [#]	18.4	56.6	19.9
Filling	77.6 [#]	14.0	67.3	16.5
Amount calories	51.4	18.8	60.3	13.6
Healthy	73.1 [#]	16.2	58.1	17.6

714