Inducing consumers to use calorie information: A multinational investigation

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Abstract

Objective: We identify individuals who set daily intake budgets and examine if an intervention making people estimate their calorie intake up to a certain point in the day helps those setting daily budgets to regulate their calorie intake for the remainder of the day, after high prior consumption.

Design: We conducted an online experiment in five countries: Australia, China, Germany, India, and the UK (n = 3,032) using a 2 (setting calorie budget: yes vs. no, measured) x 2 (intervention: intake reminder vs. control, manipulated) between-subjects design, with the amount of prior consumption measured. Participants were contacted in the afternoon. Those in the intervention condition were asked to estimate their prior calorie intake on that day.

Main outcome measures: We measured the individual characteristics of those who set daily calorie budgets and the intended calorie intake for the remainder of the day.

Results: Among people who set daily calorie budgets, the intervention reduced intended calorie intake for the remainder of the day by 176 calories if they had already consumed a high amount of calories that day.

Conclusion: A timely intervention to estimate one's calorie intake can lower additional intended calorie intake among those who set daily calorie budget.

Keywords: calorie information; nutrition labeling; menu labeling; behavior change; intervention; mental budgeting

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Introduction

Obesity is a challenging public health problem worldwide (World Health Organization, 2018). The overconsumption of calories is a primary cause of weight gain (Livingston, 2012; World Health Organization, 2018), and policymakers across the globe have tried to implement various initiatives to help people reduce excessive calorie intake (Roberto, 2015). One of the most popular types of initiative involves the regulation of nutrition labeling. To date, over 70 countries have either mandated nutrition labeling or have introduced voluntary labeling systems (European Food Information Council, 2018). However, while many consumers across countries report using nutrition labeling in some way (Campos et al., 2011), they do not use the information often and it is unclear how they use the information (Grunert et al., 2010; Mhurchu, 2007; Todd, 2008). Similarly, despite the introduction of menu labeling at restaurants in the USA, meta-analyses reveal that its effect is either insignificant (Long, 2015) or disconcertingly weak in reducing calories in items chosen (Bleich, 2017; Zlatevska, 2018). This might be caused by a lack of understanding, leading to calls for increased education about nutrition knowledge (Abel, 2015; Elbel, 2011; McCrory, 2016). However, while enhancing caloric knowledge is necessary to support the use of calorie information, improved knowledge does not always translate to intentions (Burton, 2012). This suggests that policy makers should go beyond mandating information disclosure and providing daily calorie requirements, which have been the main focus of existing policy regulations (Kanter et al., 2018), and somehow induce people to incorporate this information into their plans, intentions, and actions.

Given the limitations of existing labeling regulations in instigating population-level behavioral change (Barker et al., 2012; Campos et al., 2011), it is critical to understand *who* is likely to use such information, and *when* and *how* they may incorporate information from labels

into their decisions (Burton, 2012). Such understanding is central to one of the main policy objectives of nutrition labeling, which is to help people make better decisions about food (McGuire, 2016; U.S. Department of Health and Human Services (HHS) & U.S. Department of Agriculture (USDA), 2015). In this study, we aim to identify who might use calorie information to regulate their calorie intake, which requires motivation as well as knowledge related to nutrition (Burton, 2012), and examine the conditions under which they actually do so.

To examine who uses calorie information and how they do so for intake regulation, one key insight is that people can balance their intake across consumption decisions within a day (Khare, 2006, 2009), and hence calorie information at one time may be used to regulate calorie intake at another time. However, most research on the effectiveness of labeling has studied how providing nutrition information about a given food item affects the choice of that specific item (Zlatevska, 2018), not taking a bigger-picture view of how information provision can influence self-regulation of calorie intake across consumption decisions (Oh et al., 2020) and throughout the day. Therefore, we identify people who have daily calorie budgets as a group who will likely use calorie information for daily intake regulation. We also design an intervention that facilitates the use of calorie information among those having daily calorie budgets to regulate their calorie intake on a daily basis.

People who set daily calorie budgets

To successfully regulate calorie intake, people need to be aware of calorie information, which is available from various sources such as nutrition and menu labeling (Burton, 2012). However, for this information to be useful, they need to have accurate nutrition knowledge including daily calorie requirements (Abel, 2015; Bleich, 2010; Elbel, 2011; McCrory, 2016). Thus, enhancing nutrition knowledge has been emphasized as a way to enhance the effectiveness

of labeling regulations (Breck, 2017; Miller & Cassady, 2015). However, including recommended daily calorie needs on food labels has revealed inconsistent effects across experiments (Downs, 2013; Roberto, 2010). Nutritional knowledge by itself does not appear to motivate uninterested consumers to use information from labels (Burton, 2012; Miller & Cassady, 2015). This suggests that in addition to information awareness and knowledge, motivation is essential.

We propose that those who are motivated to regulate their daily calorie intake are likely to set their own daily calorie budgets (Krishnamurthy, 2010). The process of setting a calorie budget requires both nutritional knowledge and motivation to regulate calorie intake. People need to know their daily calorie requirements and make adjustments according to their own goals and needs. A person's use of labeling depends on demographic characteristics such as gender, education, and interest in health and diet, as reflected in nutrition knowledge and motivation to control weight (Campos et al., 2011; Grunert, 2010; Larson et al., 2018; McCrory, 2016; Moorman, 1996; Oh et al., 2016; Siu, 1998). Based on these prior research findings, we predict that people who set their daily calorie budgets are more likely to be women, high in nutrition knowledge, and interested in health and diet.

Situational need to regulate calorie intake

We propose that a situational need to regulate calorie consumption should be activated for those with daily calorie budgets to intend to change their subsequent intake decisions. As with financial budgets, where people who have restricted budgets reduce subsequent expenditure after a large outlay (Read, 1999), we suggest that people who "spend" a lot of their calorie budget earlier in the day have a high situational need to regulate calorie intake later in the day. When the remaining calorie budget is ample (i.e., when they have not eaten much early in the

day), people would be less concerned about over-consumption later in the day. In contrast, when the remaining calorie budget is tight (i.e., when they have already eaten a lot early in the day), the situational need to regulate calorie intake would be greater later in the day (Krishnamurthy, 2010). Thus, we hypothesized that a situational need to regulate calorie intake should be high for those who have daily calorie budgets to try to change their consumption decisions based on calorie information.

The intervention: to increase the salience of the situational need for calorie regulation

While financial information for monetary budgets tends to be available or calculable after each purchase (Heath, 1996; Thaler, 1985), prior calorie intake information pertinent to daily calorie budgets is not readily available after consumption. Since tracking and accounting for one's prior calorie intake requires substantial attention and effort (Harvey et al., 2019), one might fail to account for the cumulative calorie intake information, which indicates one's situational need for intake regulation. If people do not realize their situational need, they likely will not become motivated to regulate their calorie intake. To help people behave consistently with their motivation, behavioral researchers suggest carefully designed interventions be developed such as *nudges* (De Ridder et al., 2020) and *boosts* (Hertwig & Grüne-Yanoff, 2017). While various kinds of interventions that aim at behavioral changes for healthy eating tend to lead to positive changes (Thomson & Ravia, 2011), it has been highlighted that the aim of the intervention needs to be aligned with one's needs and goals to be effective (De Ridder et al., 2020; Venema et al., 2019). To this end, we propose an intervention that prompts people to estimate their cumulative calorie intake for the day, thus indirectly bringing to mind the

situational need to regulate calorie intake based on prior cumulative calorie intake.[1] This intervention is likely to work among those who have calorie budgets since they would consider the relevant information to achieve their regulatory goal. When people with calorie budgets have a high situational need for calorie intake regulation (e.g., if they have already consumed many calories at breakfast and lunch on a given day), such an intervention would help them realize that they have a tight remaining budget, and, as a result, they should intend to consume fewer calories later (e.g., at dinner). In contrast, when they have a low need for regulation (e.g., because they consumed relatively few calories at breakfast and lunch), the intervention would not restrict subsequent consumption because they have a relatively ample calorie budget still available that day. Finally, the intervention should not have any effect for those who do not set daily calorie budgets.

[1] It is important to note that we did not label our intervention as either a 'nudge' or a 'boost' due to its lack of fit with either kind of intervention. Nudges and boosts both aim to direct behaviors in a specific direction while maintaining the autonomy of decision makers (Hertwig & Grüne-Yanoff, 2017; De Ridder et al., 2020). In contrast, the present intervention simply requests people to estimate calorie consumption. Unlike nudges, the intervention did not aim to leverage any existing heuristics or biases (De Ridder et al., 2020). And unlike boosts, it did not aim to enhance competence in making healthy eating decisions (Hertwig & Grüne-Yanoff, 2017). Hence, we chose to label this intervention more generally and non-specifically, rather than calling it either a nudge or a boost. We thank the reviewers for sharing their valuable perspectives in this discussion.

Further, we predict that the intervention should not produce the same effect among those who merely know about daily calorie needs even when they have a high situational need for regulation. This prediction is based on previous findings that nutrition knowledge does not equate to motivation to consume in accordance with that knowledge (Burton, 2012). An individual who possesses the requisite nutrition knowledge may not be interested in using nutrition information from labels at a given point in time and/or exerting themselves to engage in healthy eating practices. Indeed, introducing daily or per-meal calorie intake recommendations at fast food restaurants did not reduce consumed calories even when calorie information for specific items was available (Downs et al., 2013). Together, these suggest that while knowledge may be necessary, it is not sufficient; and motivational factors may play a key role as well (Miller & Cassady, 2015).

We conducted a large-scale, multi-country experiment to test our predictions and evaluate the effectiveness of the intervention on respondents' intended calorie intake. Specifically, we aimed (a) to identify characteristics of those who are likely to set their daily calorie budgets and (b) to test the effectiveness of our intervention in increasing intentions to regulate calorie intake when the situational need is high among those with calorie budgets, not among those with the knowledge of daily calorie needs.

Methods

Sample

We recruited participants from five different countries: three high-income Western countries (Australia, Germany, and the UK) and two Eastern countries (Hong Kong in China, and India). The prevalence of obesity has risen in all five countries in recent decades (World Health Organization, 2017), and nutrition labeling for packaged food products has been

mandated in these countries, requiring similar items (e.g., energy and macronutrients) to be listed (see Supplemental online materials Table A1).

In total, 3064 adults, aged 18 years or older, were recruited online ($n_{Australia}$ = 712; $n_{Germany}$ = 730; $n_{Hong\ Kong}$ = 218; n_{India} = 703; n_{UK} = 701) via Qualtrics Panels. The study was conducted as part of a larger cross-national investigation of food consumption behaviors. All participants received an identical survey, in English, except in Germany where it was translated into German. We had initially planned to recruit 600 participants from each country. However, because the available participant pool of eligible English-speaking Hong Kong panelists was smaller than the country-level pools, it became clear during data collection that it would be difficult to recruit 600 respondents from Hong Kong. Thus, we decided to collect more data from the other countries, arriving at a final tally of more than 700 participants in the remaining four countries. We collected the data from 7 July to 18 August, 2017. All procedures were approved by the relevant ethics committee at the third author's university. Informed consent was electronically obtained from all participants.

Before analyzing the data, we excluded responses from 32 participants (exclusion rate: 1.04%) because 2 participants reported having been fasting, 29 participants (including one who reported having been fasting) failed to follow the instructions (e.g., reported non-food items), and 2 participants entered extreme outliers in the measures (e.g., over 100000 calories as their planned calorie intake). The final sample of 3032 respondents was used for the following analyses. Given the sample size and the assumption of equal sample sizes of groups who have calorie budgets versus not, the sensitivity analysis yielded a detectable effect size of f = .05 (corresponding to a small-size effect) with alpha of .05 and power of .80.

Design and procedure

Our study had two objectives: (a) examining characteristics of those who have daily calorie budgets; (b) testing the effectiveness of the intervention when the situational need is high for those with calorie budgets versus those with daily intake knowledge. Regarding the second objective, our intervention study had three orthogonal independent variables: Calorie budgets (operationalized as whether participants set themselves a daily budget or not, measured), situational need (operationalized as the number of items consumed that day, measured), and the intervention (asking respondents to estimate the amount of calories they had consumed earlier that day, or not, manipulated between subjects as described below).

Respondents were contacted only between 4 PM and 6 PM in their local time to ensure that they had eaten at least one meal or snack but had not yet had dinner when they recorded their responses. In the beginning, we measured calorie budgets with a dichotomous variable, following previous research (Lee & Thompson, 2016). Specifically, we asked participants, "Do you set a limit for yourself in terms of the number of calories you eat on an average day (yes/no)." Those who answered 'yes' to this question were then asked the size of their daily calorie budget. Then all participants were asked "Do you know how many calories, on average, you should eat per day? (yes/no)," and only those who indicated that they knew were asked to provide their recommended daily intake (Breck, 2017; Krukowski, 2006).

Next, we asked participants to recall and list what they had eaten or drunk from the moment they woke up until the time of the experiment, and to note alongside the time that they consumed the item, and whether it was for breakfast, lunch, or a snack (e.g., "breakfast: eggs and toast, coffee, 9 am"). After they had listed everything that they had eaten or drunk, participants were randomly assigned either to the intervention (n = 1510) or to the control condition (n = 1522). Participants in the *intervention* condition were shown all the food/drink items that they

had listed and were asked to estimate how many calories they had consumed (see Appendix A). In contrast, participants in the *control* condition were also shown all the food/drink items that they had listed but were not instructed to carry out a calorie estimation. We then measured the main dependent variable by asking all participants to indicate how many calories they intended to consume from then until the end of the day. They also answered several questions related to the timing of the study (e.g., "what time is it now?") and then a set of questions from an unrelated study (e.g., "How tasty do you think a brownie is?"; "How healthy do you think broccoli is?"; "Things that are good for me rarely taste good."). These questions were added after the intervention manipulation, and the measured dependent and independent variables of interest for the current study. Consequently, these items could not have interfered with this study. Lastly, participants indicated their eating restraint (10-item dietary restraint scale (Herman & Polivy, 1980)), how much they were motivated to lose weight on a 7-point Likert scale (1 = not motivated at all; 7 = extremely motivated), whether they had an exercise goal (yes vs. no), their weight and height in their preferred unit (e.g., pounds or kilograms for weight; feet and inches or meters and centimeters for height), and demographic information, including age, gender, education, and employment status. We calculated body mass index (BMI) from self-reported weight and height and categorized respondents into four groups (underweight, normal, overweight, and obese).

We used the number of items consumed as the situational need for intake regulation, which allowed us to observe the natural variation in the situational need for regulation in a real-life setting. Because the information provided by participants did not include details about the amount of food that they had consumed, two independent coders counted the number of food/drink items that each participant had listed, except for light condiments (e.g., spices) and

items that contained 10 or fewer calories per serving (e.g., water). The counts of two coders showed high reliability of .941, and their differences were resolved after the discussion to determine the number of items for each participant. We used this measure (M = 6.62; SE = 2.95; *Median* = 6.00) as a proxy for the prior calorie intake. To test for robustness, we conducted a nonparametric correlational analysis between the number of items and participants' calorie estimates in the intervention condition (n = 1510) as the relationship between these variables was monotonic, and found a significant positive correlation (Spearman's ρ = .24; p < .001). This suggests that using the number of listed items is an acceptable proxy for prior calorie intake. When we split the data on knowledge of daily calorie intake, the correlation was high among those who knew their daily calorie intake (Spearman's ρ = .35; p < .001) relative to the correlation among those who did not know (Spearman's ρ = .16; p < .001). These results support the validity of this measure of prior intake, particularly among those who knew their daily calorie needs.

We used calories as the energy unit in all countries except for Australia where we used kilojoules because kilojoules are the standard measure for food energy in Australia. When analyzing the data, we converted Australians' responses in kilojoules to calories except for those respondents who explicitly indicated that they had used calories.

Analysis

First, to examine the characteristics of those who have versus those who do not have calorie budgets, we used χ^2 tests for categorical variables, and one-way ANOVAs for continuous variables. We tested their differences in gender, age, education, weight status, knowledge of daily calorie need, presence of an exercise goal, size of daily calorie need, dietary restraint, and

motivation to lose weight. Binary logistic regressions were conducted to estimate the probabilities of having calorie budgets.

Second, to test the effectiveness of the intervention, we estimated a multilevel model, controlling for country-level variations. Specifically, we regressed planned calorie intake on an intervention dummy variable (0 = control, 1 = intervention), the number of items consumed before the task (standardized), a dummy variable representing daily calorie budgets (0 = don't have a budget, 1 = have a budget), and all possible two-way and three-way interactions between these variables, controlling for age and gender (0 = male, 1 = female) with country-level random effects. Age and gender were controlled for since they are determinants of the daily calorie need at rest, i.e., basal metabolic rate (Henry, 2005), and dietary recommendations are usually made according to gender and age (HHS & USDA, 2015). Upon observing a significant three-way interaction, we tested separate interaction contrasts between prior food intake and the intervention among those who have calorie budgets and those who do not have calorie budgets, and then conducted simple contrasts for the intervention at varying levels of prior food intake among those who have calorie budgets. Additionally, we tested for robustness conducting the multilevel model analyses without the covariates, and/or standardizing the prior intake measure and with a set of additional covariates as well as after excluding a specific country sample. In addition, to test the role of knowledge of daily calorie requirement instead of daily calorie budgets, we conducted the same multilevel analysis replacing the budget-setting variable with knowledge of the recommended calorie requirement. We considered $p < .05$ as statistically significant, and $p < .10$ as marginally significant. Except for the multilevel analysis for which we used Stata (version 13), we performed all analyses using IBM SPSS Statistics (version 22).

Results

Participant characteristics, calorie need knowledge, and calorie budgets

Table A2 in Supplemental online materials reports the demographic characteristics of participants from each country. Table A3 in Supplemental online materials presents the descriptive statistics for the measures broken out across the five countries. Overall, 47.4% of respondents (n = 1438) reported that they knew the recommended daily calorie intake. In all countries except Australia, the proportions of respondents reporting that they knew their daily calorie needs were close to or above 50% (61.3% in the UK; 54.6% in Germany; 51.6% in India; 47.2% in Hong Kong; 22.5% in Australia). The average recommended daily calorie intake as reported was 1991 calories (*SD* = 661). However, only 24.7% of the sample (n = 750) indicated that they set calorie budgets (37% of respondents in Hong Kong; 36.8% in India; 27.9% in Germany; 20.1% in the UK; 10.7% in Australia), showing a significant gap between knowledge of daily calorie intake need and adoption of calorie budgets. The average size of the daily calorie budgets from the five countries was 1915 calories (*SD* = 889).

Characteristics of people who have calorie budgets

To examine the characteristics of people who have daily calorie budgets, we compared those who reported that they had daily calorie budgets with those who did not, using the pooled data first and then the data within each country (see Supplemental online materials Table A4). The analyses conducted with the pooled data revealed that those with a daily calorie budget tended to be younger ($p < .001$), female ($p < .001$), highly educated ($p < .001$), less likely to be obese ($p = .004$), more likely to claim that they knew the recommended daily calorie intake ($p < .001$), more likely to have an exercise goal ($p < .001$), and showed higher dietary restraint ($p < .001$) and motivation to lose weight ($p < .001$), compared to those who did not. Similar patterns were found across countries. The results are consistent with the known demographic and

behavioral correlates of the use of menu labeling and nutrition labeling (Feng, 2018; Oh et al., 2016; Todd, 2008). Please see Supplemental online materials Table A5 for predicted probabilities of setting daily calorie budgets, obtained from a series of binary logistic regressions.

The effects of the intervention by situational need and calorie budgets

We predicted that our intervention would reduce subsequent intake intentions among participants who have daily calorie budgets under the high situational need for calorie regulation. The multilevel model with a country-level random effect (country random effect = 71365.39, *SE* =46067.23, 95% *CI* [20138.48, 252899.9]) was significantly different from a linear regression that did not account for the random effect ($\chi^2_{(df=1)}$ = 267.77, $p < .001$; model 1 of Supplemental online materials Table A6). The interclass coefficient for country was .14 (*SE* = .08, 95%*CI* [.04, .37]), suggesting that the intended intake was weakly correlated within the same country. More importantly, the multilevel model showed that none of the main effects or two-way interactions were significant, but the three-way interaction was significant (*b* = –135.05, *SE* = 57.75, *z* = –2.34, *p* = .02, 95%*CI*[–248.24, –21.85]), along with significant effects of gender (*b* = –129.49, *SE* = 24.90, *z* = –5.20, *p* < .001, 95%*CI*[–178.29, –80.69]) and age (*b* = –4.20, *SE* = .86, *z* = –4.87, *p* < .001, 95%*CI*[–5.89, –2.51]). Given the small effect size of the three-way interaction (*f* = .043), the estimated power of this three-way interaction was .65. To probe this three-way interaction, we tested two-way interaction contrasts between intervention condition and prior calories consumed, separately among those who had calorie budgets and those who did not have budgets. The two-way interaction contrast was marginally significant among those who had budgets (*b* = –90.33, *SE* = 50.90, z = –1.77, *p* = .076, 95%*CI*[–190.09, 9.42]), but not significant among those who did not have budgets (*b* = 44.71, *SE* = 27.28, *z* = 1.64, *p* > .10,

95%*CI*[–8.75, 98.18]). As previous research has justified conducting simple slopes analyses based on a marginally significant interaction for a theoretically-derived a priori prediction (Gailliot & Baumeister, 2007; Logel et al., 2019; Ma et al., 2017; Verhoeven et al., 2014), we further conducted simple slopes analyses among those who had daily calorie budgets to test the effect of the intervention after having consumed a large or a small number of food items. We selected 1 *SD* above/below the mean of the number of food items consumed as values representing high or low prior intake, following the conventional value selection practice with continuous variables (Cohen & Cohen, 1975; Finsaas & Goldstein, 2020; Liu et al., 2017). As predicted, among those who had daily calorie budgets and had consumed greater quantities of food earlier in the day (1 *SD* above the mean), the intervention reduced the number of calories they planned to consume later in the day (b = –176.29, *SE* = 71.93, z = –2.45, p = .014, 95%*CI* [–317.27, –35.31]; see Supplemental online materials Figure 1A). In contrast, among those who had calorie budgets but had consumed smaller quantities of food earlier that day (1 *SD* below the mean), the intervention did not significantly affect their calorie intake plans (b = 4.37, *SE* = 68.45, z = .06, p =.95, 95%*CI* [–129.79, 138.54]). Additionally, since the Johnson-Neyman technique (Johnson & Fay, 1950) is recommended for testing the simple effect of the intervention in the broad ranges of the moderated continuous variable (Spiller et al., 2013), we conducted a Johnson-Neyman (J-N) analysis. This revealed J-N point of .11 *SD* (b = –95.89, *SE* = 48.96, z = –1.96, p = .050, 95%*CI* [–191.86, .07]), which suggests that among those who had calorie budgets, the effect of the intervention became significant at .11 *SD* above the mean of prior calorie intake.

The effects of the intervention by situational need and mere knowledge

As predicted, if we replaced in the model those who had calorie budgets with those who merely knew the recommended daily calorie intake, the same pattern of effects did not emerge(3-way interaction, b = –33.07, SE = 48.09, z = –.69, p = 0.49, 95%CI [–127.33, 61.19]) with no other main effect or two-way interactions being significant (ps > .12), except a significant main effect of the knowledge of recommended calorie intake (b = 126.26, SE = 34.94, z = 3.61, p < 0.001, 95%CI[57.78, 194.73]). Even among those who reported knowing their daily calorie intake, the intervention did not change their intentions, neither after high prior intake (at 1SD above the mean of prior intake, b = –74.90, SE = 48.25, z = –1.55, p = 0.12, 95%CI [–169.47, 19.68]) nor after low prior intake (at 1SD below the mean of prior intake, b = –74.57, SE = 50.31, z = –1.48, p = 0.14, 95%CI [–173.18, 24.03]). This suggests that simply knowing how many calories one should consume is not sufficient for the intervention to motivate regulatory intentions even when the situation makes the amount of food consumed earlier in the day salient.

Robustness checks

We also tested our model by dropping the covariates (age and gender) and standardizing the dependent variable, and the results supported the robustness of these findings (models 2–4 of Supplemental online materials Tables A6 and A7).

We tested if the effects remained similar after further controlling for another set of covariates beyond age and gender: how many hours participants had stayed awake, whether they had knowledge of daily calorie need, and BMI (models 5, 6, and 7 of Supplemental online materials Tables A6 and A7), respectively due to the possible effects of these variables on the dependent variable. Reassuringly, these models controlling for additional covariates produced the same directions of the effects and the same levels of statistical significance.

Additionally, due to the potential for confusion between kilojoules and calories in the Australian sample, we conducted the same analysis as the main model after excluding the Australian responses (see model 8 of Supplemental online materials Tables A6 and A7). The patterns remained similar to those observed with the pooled data, but significance levels changed for some interactions (see Model 8 of Tables A3 and A4 in Supplementary Materials).

Country-by-country results

We also obtained the estimates by country (see Supplementary online materials Figure A2) by running the same regression model separately for each country. The results show that the negative direction of the intervention effect after high prior intake among those with calorie budgets was observed consistently across countries, except Germany. We discuss this exception in the following section.

Discussion

This research examines (a) who are likely to use calorie information for their daily intake regulation and (b) whether the proposed intervention can induce consumers to incorporate calorie information into their self-regulated daily calorie intake plans. In addressing the first objective, across five countries, we identified people who hold daily calorie budgets—reflecting their knowledge *and* motivation to control their energy intake—are more likely to use calorie information. They were more likely to be women, younger, highly educated, and have an interest in health and diet, consistent with prior findings of the correlates of labeling use (Campos et al., 2011; Grunert, 2010; Larson et al., 2018; McCrory, 2016; Moorman, 1996; Oh et al., 2016; Siu, 1998). Furthermore, in addressing the second research objective, we found support for the efficacy of the proposed intervention in inducing people to incorporate calorie information into their daily calorie intake plans. Among people who had daily calorie budgets, the intervention

asking to estimate prior cumulative calorie intake successfully reduced their intended calorie intake if they had already eaten a lot in the day. The same intervention, however, did not have a significant effect on their planned calorie intake if they had not eaten much earlier in the day. The different effects of the intervention depending on prior intake suggest that changes in regulatory intentions may occur only when people have a situational need to control their intake. Also, as predicted, the intervention did not produce the same effect after high prior intake among those who merely knew their daily calorie need, which supports the idea that knowledge of calorie information alone is not sufficient for the intervention to have its influence.

The size of the intervention effect is not negligent. Given the exchange rate of a 1 kilogram of body fat to 7,700 calories (Hall, 2008; Sivak, 2006) and assuming successful translation of intentions into behaviors, eating 176 calories less due to the intervention for about 44 days will lead to a loss of 1 kilogram of body fat. This means that among those who keep daily calorie budgets, a timely reminder of how much they ate earlier in the day could help them manage their weight. Hence, the present intervention is worth attention for further research and application.

The findings provide several policy implications. The spread of nutrition labeling is a beneficial policy development as it helps increase awareness of nutrition information and even can induce supply-side changes to food service industries (Oh et al., 2016). As discussed, much effort is being placed on increasing awareness of nutrition information and daily calorie needs. However, our study further suggests that there are other key factors to consider to increase the actual use of nutritional information in one's plans to regulate calorie intake. Since only individuals whose goals and plans align with the objectives of interventions are likely to change their decisions due to the interventions (De Ridder et al., 2020; Hertwig & Grüne-Yanoff, 2017),

our findings suggest that people must have daily calorie budgets for the intervention to change their consumption plans. Furthermore, making people more mindful of their earlier consumption can increase the impact of nutrition information provision on their planned food decisions by highlighting the situational need for control when their remaining calorie budget is tight. However, our results also suggest that currently, the proportion of people who have daily calorie budgets is not very large.

It has been suggested that food labeling policies be complemented with educating people about aspects of nutrition, such as daily calorie need (Breck, 2017). However, although about half of the respondents in our study reported that they knew their daily recommended calorie intake, many did not set daily calorie budgets and did not intend to change their intake in response to the intervention. This is consistent with previous research showing that the provision of recommendations for daily calorie intake is not always successful in reducing intake (Downs, 2013; Roberto, 2010; Wisdom, 2010). Our findings suggest that policies should aim not only to improve nutrition knowledge but also to target those who have already set their daily calorie limit. In this study, about 25% of participants had daily calorie budgets. They showed the intention to regulate their calorie intake when the intervention made them become aware of their need to regulate. Also, we found a gap between knowledge of calorie intake needs and calorie budget setting, which leads us to call for further investigation of how to motivate people to translate their knowledge of daily calorie needs into dietary targets.

Our intervention bears some similarities to calorie-counting devices or applications, which can provide more accurate estimates of one's cumulative calorie intake (e.g., MyFitnessPal) (Harvey et al., 2019; Jakicic, 2016). However, while such calorie counting services are usually subscribed to by those who have a strong motivation to lose or control

weight (Goldstein, 2017), our intervention was not exclusively tested amongst existing users of such services. Also, unlike calorie-counting services, which require frequent attention and substantial time (Harvey et al., 2019), our findings show that even a single reminder of prior calorie intake can help people intend to regulate their intake as long as the reminder is timely at a critical moment of the day (e.g., before dinnertime).

It is important that the timing of the intervention should be carefully determined. We decided to uniformly provide the intervention in the late afternoon when most people are waiting for dinner, often the largest meal of the day (Khare, 2009). However, because people differ in their meal schedules and how much they eat at each meal, individualizing times for the intervention would likely be more effective.

Limitations and future research

While our results are in line with our proposed theory, this investigation has a few limitations. First, in implementing our intervention, we relied on peoples' self-generated estimates of prior intake rather than objective calorie information. People may fail to precisely remember calorie information from labels and other sources (Todd, 2008), leading to inaccurate estimates. If these estimates are not accurate, subsequent adjustments may not be adequate (Chandon, 2007; Chernev, 2011; Martin, 2007). Also, the intended calorie intake relied on one's self-report, which poses the same accuracy problem as estimates of prior intake (Block et al., 2013). We did not provide a reference value for the intended intake due to the different levels of prior intake across individuals and the possibility to bias the intended calorie intake measure. However, the absence of a reference might have led to difficulty in generating responses, particularly among those who were not familiar with food energy.

Second, although the data were collected during the designated afternoon time based on

the assumption that participants would consume another major meal after the study, we did not measure whether they might already have had dinner at the time of participation. Therefore, we may have inadvertently included people who had eaten dinner already. Related to this possibility, unlike other countries in our panel sample that have a single time zone, there are multiple time zones with 2.5 hours maximum difference in Australia, and therefore, we may have allowed Australian participants from outside of the intended time window. Since only a very few respondents (0.5%) participated slightly outside of the intended time window (e.g., 1.2 hours difference at the maximum), we retained their response in the analysis. Excluding these responses did not change the direction or statistical significance of the effects.

Third, our dependent variable was not actual calorie intake, but rather, a stated intention. Although intentions are a key determinant of actual behavior according to the theory of planned behavior (Ajzen, 1991), they do not correspond perfectly to the behavior (Sheeran & Webb, 2016; Webb & Sheeran, 2006). The intention-behavior gap (Sheeran & Webb, 2016) suggests these intentions may not translate into behavior; conversely, the mere-measurement effect (Morwitz & Fitzsimons, 2004) suggests that they might. The extent to which they do is a key question for future research. More generally, since various factors can strengthen the intention-behavior link (Sheeran & Webb, 2016), future research could examine how to increase the efficacy of the intervention through intention-behavior-gap reducing techniques such as implementation intentions (Gollwitzer & Sheeran, 2009).

We assumed that people with calorie budgets would regulate their calorie intake when reminded of how many calories they consumed in the day, consistent with the popular interest in weight loss and concerns related to obesity (Lean et al., 2018). However, some may have a weight-gain goal, which could dilute the effect of the intervention or reverse it. In our study, only

0.2% of participants indicated having a weight gain or muscle-building goal.

In addition, the country-by-country analysis revealed that while the negative effect of the intervention after high prior intake was observed consistently across countries among those with calorie budgets, the effect was not found in the same direction in the German sample. Compared to UK consumers, German consumers place a greater importance on product information when purchasing food (Brunsø & Grunert, 1998) and look for calories, sugars, carbohydrates, vitamins, and protein, and organic information more from nutrition labels (Klaus G Grunert et al., 2010). This suggests that German consumers consider various criteria in making food decisions other than calories. Despite comprehensive consideration of food information, Germans consume less fiber and vegetable and more meat-based products than the recommended amount (Heuer et al., 2015; Stephen et al., 2017), suggesting that their food consumption decisions do not necessarily account for regulating calorie intake. Our study suggests that future research should examine idiosyncratic ways by which German consumers might improve their eating practices.

In our Australian sample, knowledge of daily calorie intake and adoption of daily calorie budgets were relatively lower than in other countries, with relatively smaller budgets and lower daily intake needs reported. Although we identified who used calories as a unit instead of kilojoules, and made appropriate conversions when needed, we acknowledge that some participants might mistakenly report calories without noticing the given kilojoule unit, leading to underreporting budgets. Previous research has shown that while most Australians know that it is generally recommended to eat more fruit and vegetables, a relatively small proportion of them know how many servings of fruit and vegetables are recommended (Hendrie et al., 2008). This finding suggests a possible gap among Australians, between general knowledge of healthy diet

and specific knowledge of daily nutritional values. Reflecting such a gap, the present research shows relatively low proportions of Australians knowing their daily calorie intake and adopting daily calorie intake budgets. Although many Australians have a good knowledge of whether a given food item contains relatively a high or low level of nutrients (Worsley et al., 2014), that does not guarantee specific knowledge of their daily needs of energy and nutrients. Future investigation is required to learn more about whether and how cultural differences in nutritional knowledge influence responses to our intervention.

Lastly, although we focus on calorie reduction as a potential means to curb obesity in line with various existing policies related to nutrition and health, we acknowledge that attention should be paid to various dimensions of healthy eating, not limited to pursuing energy balance (Fernandes et al., 2019).

Conclusion

Helping people regulate their calorie intake for energy balance is a critical challenge for public policy. The present research proposed and tested an intervention that reminded people of their prior cumulative calorie intake, which helped them plan their subsequent calorie intake when they had a high situational need to regulate the expenditure of their remaining calorie budgets. Across five countries, about half of the respondents knew the recommended daily calorie intake; however, the majority of respondents did not have daily calorie budgets. This, combined with the fact that our intervention only seemed to work for those who held daily calorie budgets in influencing their intake intention, suggests a major challenge for policymakers. On a positive note, these results clearly suggest both a new way to increase the impact of the nutrition information that is increasingly available nowadays and corresponding new imperatives for public messaging and education.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author, Oh, G.G.E., upon reasonable request.

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