Journal of Economic Behavior and Organization 188 (2021) 530–551

Contents lists available at ScienceDirect

Journal of Economic Behavior and Organization

journal homepage: www.elsevier.com/locate/jebo

Does the magnitude of relative calorie distance affect food consumption?

Samir Huseynov[a], Marco A. Palma[b,*], Ghufran Ahmad[c]

[a] Auburn University, 559 Devall Dr., Auburn, AL, USA
[b] Texas A&M University, 1500 Research Parkway, College Station, TX, USA
[c] National University of Sciences and Technology, NUST Business School, H-12 Sector, Islamabad, Pakistan

ARTICLE INFO

Article history:
Received 15 September 2020
Revised 26 May 2021
Accepted 29 May 2021
Available online 18 June 2021

Keywords:
Calorie labeling
Menu dependent preferences
Self-control

ABSTRACT

Both secondary data and experimental studies offer mixed results regarding the effect of calorie information on consumed calories. Our theoretical model provides foundations to explain the heterogeneous responses found in the empirical literature by identifying two opposing forces affecting calorie intake. Informing consumers about the calorie content of food alternatives can lead to low-calorie food decisions. However, the relative calorie distance between food items can induce temptation and reduce the effectiveness of the calorie information. We implement laboratory and restaurant experiments with incentivized food choices where we exogenously manipulate the magnitude and salience of the calorie difference between food alternatives. We document that providing calorie information increases the propensity to choose the low-calorie option in the range of 3–10 percentage points. But calorie distance discounts the effect of information by 3 percentage points. Hence, the impact of calorie information depends on the relative magnitudes of these two opposing forces.

1. Introduction

Overconsumption of unhealthy and high-calorie food has become a public health crisis.[1] In response, food manufacturers and retailers are now legally required to add calorie information to their labels so that consumers can make informed choices regarding calorie intake. Since then, however, the relevant literature has reported mixed results.[2] Some empirical studies show that calorie labeling decreases calorie intake (Bollinger et al., 2011), and others find no significant changes

* Corresponding author.
E-mail addresses: szh0158@auburn.edu (S. Huseynov), mapalma@tamu.edu (M.A. Palma), ghufran.ahmad@nbs.nust.edu.pk (G. Ahmad).

[1] For instance, in the United States, and many other countries, obesity has become a national health pandemic. According to recent empirical findings, the obesity rate has already surpassed 35% in seven U.S. states (Kuehn, 2018). This rate is very alarming, mainly because it was around 20% across all states in 1995 (Ellison et al., 2014b). One of the primary reasons for the high obesity rates is the prevalence of an unhealthy diet (Cecchini et al., 2010). An unhealthy diet and consequently obesity are associated with high rates of several chronic diseases, such as cardiovascular issues (35%), hypertension (29%), high cholesterol (16%), and diabetes (12%) (USDA, 2015).

[2] See for example Tangari et al. (2019); Dallas et al. (2019); Ellison et al. (2014b,a). We provide a comprehensive review of secondary data and experimental studies on this topic in the Literature Review section.

https://doi.org/10.1016/j.jebo.2021.05.037

(Finkelstein et al., 2011; Bleich et al., 2017). Dumanovsky et al. (2011) even report an increase in calorie consumption by customers of the Subway fast-food sandwich chain after the implementation of the calorie labeling law. Previous experimental studies also yield mixed results. Pang and Hammond (2013) and Cawley et al. (2018) find that listing calorie information reduces the number of ordered calories, while Ellison et al. (2014a) do not. Thus, studies using both secondary data and experimental framework offer mixed results on the effect of calorie information on consumed calories (Fernandes et al., 2016). The impact of calorie information on calorie intake and any potentially moderating factors, therefore, remain an unsolved research question.

Recent economic models offer insight into the factors that could potentially alter the impact of calorie information on food consumption. According to Gul and Pesendorfer (2001), a decision-maker derives two kinds of utilities from a choice alternative: *normative* utility and *temptation* utility. Gul and Pesendorfer (2001) model self-control cost as the temptation utility difference between the most- and least-tempting alternatives on a menu. Noor and Takeoka (2010) show that as this difference increases, the decision-maker becomes more vulnerable to choosing the high-calorie and more tempting option. Consider, for example, an individual choosing a drink from two different menus. Facing a menu with a bottle of water and a zero calorie soft-drink induces a relatively lower temptation tradeoff compared to a menu with a bottle of water and a regular soft-drink bottle. The latter imposes a higher self-control cost on the decision-maker, since a bottle of regular-soft-drink is more tempting to the average consumer than a zero-calorie soft-drink bottle. Generally, commitments that require greater deviations from the tempting option are more difficult to accomplish. For example, overly ambitious new year's resolutions typically end in noncompliance because small deviations from the tempting option are easily manageable compared to huge leaps (Noor and Takeoka, 2010). Similarly, radical diet changes can burden the decision-maker with unbearable self-control costs, which in turn can lead to more frequent self-control failures. Noor and Takeoka (2015) argue that the outcomes of self-control efforts mainly depend on the choice-context.

Identifying the causal impact of self-control failures on economic decisions has always been a challenge because of the endogenous nature of normative and temptational utilities (Berns et al., 2007). The correlation of visceral feelings with preformed habits further contaminates the theorized causal relationship between temptational utility and self-control failure (Brown et al., 2009). In a controlled research setting, exogenously varying temptational utility differences between choice alternatives can resolve identification issues and reveal modeled causal relationships. Our primary identifying assumption is that temptation is proxied by calorie counts. Thus, we study menu-dependent temptation in an experimental setting where relative temptation differences between choice alternatives are exogenously manipulated by varying calorie differences to disentangle normative and temptational utilities and their corresponding effects. Our main choice rule is inspired by Noor and Takeoka (2010, 2015), where salience of the calorie information and visceral feelings are explicitly modeled. We propose the hypothesis that the likelihood of choosing a low-calorie alternative declines as the “calorie distance,” or the difference in the number of calories between alternatives in the menu, increases. Modeling temptation utilities with menu-dependent preferences enables us to: (a) provide a novel analysis of the potential impact of calorie-labeling laws on low-calorie food choices, and (b) explain why the literature has found mixed results.

Much like the expression “distance makes the heart grow fonder,” could the relative distance between the calories of food products make high-calorie options more attractive? Additionally, could the salience of the calorie distance between food products change food choices? We focus on food intake in binary menus by exogenously manipulating the *magnitude* and *salience* of calorie distance between food alternatives. The salience of calorie distance or integrating the causal role of the provision of calorie information on food choices enables us to study the effects of calorie labeling laws. Our theoretical model suggests that the concept of uphill self-control cost developed by Noor and Takeoka (2010) and Fudenberg and Levine (2006) is an important, previously missing link for understanding the impact of calorie information on calorie intake. We test our hypotheses in two separate experiments: a lab experiment and a lab-in-the-field experiment conducted in a national restaurant chain. Specifically, we document that informing consumers about the calorie content of food alternatives with calorie labels can lead to low-calorie and hence healthier food decisions. However, we also observe an opposing factor–temptation–when a higher calorie content serves as a signal for a tastier food product. The presence of these opposing forces and their menu-dependent relative magnitudes may explain the mixed evidence in the literature.

In the lab experiment, decision-makers are given 40 binary-choice incentivized menus and they select their preferred snack to eat at the end of the study. In the binary menus, the serving size of both alternatives is the same, so that the only difference is the calorie content of the products. Employing binary menus helps us to construct food choice problems with the same product type and brand, which is important in controlling for unobservables and in finding theorized causal relationships. Each menu has the same probability of being selected as the binding decision at the end of the experiment. In order to incentivize the experiments, participants had to consume their selected product in the binding decision in order to receive a payment. The main motivation for using binary menus is to identify the hypothesized causal relationship between the temptation distance (or calorie distance) and the probability of choosing low-calorie snacks.[3] We also apply a 2-alternative forced choice (2AFC) paradigm. Subjects have to chose one of the alternatives. In real life, most choice problems shrink to such 2AFC decisions (Vul et al., 2014), and this framework has been frequently used to study food choices (See for example, Clithero (2018); Krajbich (2018)).

[3] To study the effect of relative calorie differences on choices in menus with three or more food items, one needs to consider a more complex model that focuses on the properties of the calorie distribution (See for example, Choplin and Wedell (2014)).

The primary causal relationship of interest is also examined in the presence of the salience of the food's calorie content. The calorie distance between snack products is made salient in an *accurate* calorie information treatment and also in a *homegrown* calorie knowledge treatment compared to a control condition with no calorie information. The effect of being in a more or less tempted state of hunger is also tested by randomly assigning subjects to drink a protein shake to reduce hunger before the real food choices are offered. Thus, a 3×2 design is employed, and the calorie distance is varied in each experimental design cell. Our design allows us to study menu-dependent self-control issues in the presence of varying temptation and calorie information.

We employ a similar design for the restaurant experiment. We conduct the second experiment in a local restaurant from a national chain using full meals from the restaurant's menu. In this experiment, subjects are randomly assigned to the *No Information* control group, which receives meal descriptions but no calorie information, or the *Accurate Information* group, which receives both meal descriptions and calorie information. Subjects make food choices in 86 independent, binary menus, and similar to the lab experiment, one of the menus is randomly selected at the end of the experiment as the binding menu. Subjects are only allowed to eat the meals inside the restaurant and are not allowed to share food with anyone. The restaurant experiment enables us to test our hypotheses with actual meals in a restaurant setting, and with greater relative calorie distances compared to the snacks in the lab experiment. An important aspect of our designs is that we do not introduce the price attribute in menus. In the lab experiment, we use alternatives from the same snack type and brand which also have the same market price. In the lab-in-the-field experiment, the price of the meals are identical, and we manipulate the calorie difference by changing side items.

The main result of the lab experiment is that food choice outcomes depend significantly on the calorie distance between food alternatives. We develop a theoretical model where we formulate self-control cost building from the work of Gul and Pesendorfer (2001) and Noor and Takeoka (2010, 2015). Our analyses suggest that the calorie difference variable is a good proxy for the incurred self-control cost. Specifically, we show that there is a significant and positive relationship between the number of calories in snacks and the degree of temptation the snacks generate.

We show that the effect of calorie information depends on the relative calorie difference. In the lab experiment, subjects are more likely to exhibit self-control and choose low-calorie snacks when they know (the Accurate Information Condition) or believe (the Homegrown Information Condition) that a higher calorie distance exists between the snacks compared to the control condition. This effect, however, is small and mostly offset by the effect of the calorie distance. This result offers a plausible explanation for why calorie labeling laws have not generated the desired outcome of reducing calorie intake (Bollinger et al., 2011; Dumanovsky et al., 2011). In our theoretical model, we show that the experienced menu-dependent self-control cost (i.e., the calorie distance) discounts the effect of calorie information. Our results also indicate that when subjects incur higher self-control costs facing menus with higher calorie differences, they tend to overestimate the calorie content of low-calorie snacks to a greater extent, which in turn significantly decreases the likelihood of choosing the low-calorie snacks.

We also confirm our primary hypothesis in the restaurant experiment. An increase in the calorie distance reduces the probability of choosing the low-calorie alternative, and providing calorie information increases the number of low-calorie choices. Visual attention to meal descriptions, measured using an eye tracking device, moderates the effect of calorie information.

The rest of the paper is organized as follows: Section 2 discusses the policy relevance of our study and its place in the related theoretical choice literature. Sections 3 and 4 present the experimental design and theoretical model used to derive our hypotheses, respectively. Section 5 discusses the results, and Section 6 concludes.

2. Related literature

2.1. Models on temptation and self-Control

Self-control and time-inconsistent preferences have become one of the central apparatuses of economic research since Strotz (1955) modeled an economic agent's multi-period consumption decision. Strotz (1955) showed that the agent would not follow the optimal future consumption plan determined at the present moment because he has a steeply decreasing discount factor. This line of research was later improved by modeling different discount functions (Laibson, 1997; Angeletos et al., 2001; O'Donoghue and Rabin, 1999), recency bias (O'Donoghue and Rabin, 1999), and strategic interaction of short-run and long-run selves (Levine and Fudenberg, 2006). In Strotz's model, the decision-maker does not have any willpower and quickly succumbs to temptation (Masatlioglu et al., 2016). Notice that, under the neoclassical economic modeling framework, a rational economic agent has infinite willpower, and therefore, never experiences self-control issues. Reality falls somewhere in between, where agents have limited willpower (Muraven and Baumeister, 2000) and may or may not succumb to temptation. It has been shown that willpower can be choice-context specific (Fudenberg and Levine, 2012).

The seminal paper of Gul and Pesendorfer (2001) was the first attempt to show that Strotz's model can be formulated with dynamically consistent and complete preferences (Ericson and Laibson, 2018). Their work led to the development of menu-dependent preferences (Gul and Pesendorfer, 2004; Dekel et al., 2001; 2009; Noor, 2007; 2011; Toussaert, 2018) where the decision outcome depends on menu-dependent self-control (Noor and Takeoka, 2010; 2015). The major distinctive idea of this literature is that temptation is not only an intrinsic feature of a choice alternative, but it can also become more severe or less "damaging" depending on the availability of other alternatives in the choice set. A decision-maker incurs different self-control costs depending on the menu he faces. The recent replication crises in ego-depletion research and its vague domain-generality assumption motivate modeling menu-dependent preferences and self-control costs instead of universal self-control resources (Lurquin and Miyake, 2017; Hagger et al., 2016). Our study makes an important contribution to this literature by modeling and quantifying menu-dependent self-control and linking the incurred cost to incentivized food choices.

2.2. Public policy and calorie labeling laws

Our study aims to scrutinize the effectiveness of the provision of calorie information when the choice object can induce visceral feelings of temptation. Conventional economic models predict that agents optimize their choices by attending to all relevant information. One of the main predictions of the existing Information Economics literature is that consumers decide with the help of product-related information, and they will seek information until the search cost exceeds the benefit (Stigler, 1961; Nelson, 1970; 1974). However, recent studies show that consumers can exhibit myopia; they can fail to pay complete attention to product attributes, and their focus can be altered depending on the choice-context (Gabaix et al., 2006; Kőszegi and Szeidl, 2012; Bordalo et al., 2013; Masatlioglu et al., 2016; Huseynov et al., 2019). Consumers are subject to visceral feelings that can further exacerbate the quality of choice outcomes (Gul and Pesendorfer, 2001; Muraven and Baumeister, 2000; Noor and Takeoka, 2010; Levine and Fudenberg, 2006; Noor and Takeoka, 2015; Alós-Ferrer et al., 2015). From this perspective, our study joins a critical conversation on the effect of calorie labeling laws on food choices.

It has been argued that food availability issues can depreciate the quality of daily nutritional intake. "Food desert" —areas with limited access to healthy and affordable food— have been shown to deteriorate public health (Morland et al., 2006; Beaulac et al., 2009). The main part of the existing literature mainly focuses on the availability of healthy food to overcome diet-related chronic diseases. Recent studies also explain the poor-diet and poor-health relationship through distracting cues that appear in food decision-making environments. Cooksey-Stowers et al. (2017) show that "food swamp" neighborhoods, with overwhelming access to junk and fast-food restaurants, predict obesity better than "food deserts." Perhaps the consumption of unhealthy food is not only driven by limited accessibility to healthy food but also by preferences for "tastier" high-calorie food products (Allcott et al., 2019). Apart from the price incentive of consuming affordable cheap food (Ghosh-Dastidar et al., 2014), unhealthy diets have also been explained by succumbing to temptation and lack of self-control (Gul and Pesendorfer, 2001; Noor and Takeoka, 2010; Palma et al., 2018). Public health advocates might find it hard to propagate completely switching to fruit, fiber, and vegetable-intensive food diets because of budget and food culture restrictions. However, encouraging less calorie intake seems a plausible strategy in combating the obesity epidemic. Menus in many fast-food restaurants include high and relatively low-calorie food items, and thus, choosing low-calorie alternatives can be an initial step towards a healthy diet, and it can eventually lead to improving public health. It is not controversial to expect that habitual food preferences are inelastic in the short-run (Camerer, 2013). Therefore, finding appropriate behavioral mechanisms to encourage the consumption of relatively low-calorie food items can be a feasible and more effective policy alternative.

In 2008, New York City became the first jurisdiction in the United States to require restaurant chains to visibly post calorie information in their regular menus (Elbel et al., 2009). This policy initiative was later adopted by several states, including California, Massachusetts, and Oregon, and eventually became a nationwide law, effective May 2018 (Cawley et al., 2018). The law is binding for retailers including bakeries, coffee shops, movie theaters, and restaurant chains with 20 or more locations (Cawley et al., 2018). Follow-up studies report mixed results regarding the outcomes of the NYC calorie labeling law.

The existing literature offers a limited explanation of why the numeric calorie information is not effective in terms of encouraging low-calorie choices (Bollinger et al., 2011). Ellison et al. (2014a) find that numeric calorie information does not yield the expected policy outcome in calorie-labeling laws. Tangari et al. (2019) find that when the actual amount of calories of food items is less than the expected level, subjects tend to over-consume. Tangari et al. (2019) report that this "backfire effect" is observed when a snack product on the menu is perceived as "unhealthy." Their research suggests that temptation to food products may impact the effectiveness of numerical calorie information. Of course, each consumer's belief about the number of calories in a product is endogenous. Individual biases and heterogeneity define the way economic agents perceive and process calorie information. Tangari et al. (2019) suggest that by increasing the serving size, food manufacturers can also increase calories per serving, and nudge consumers towards less calorie intake. It has also been found that even the location of the calorie information on food labels matters in terms of healthy eating behavior. Dallas et al. (2019) find that since the United States population reads from left-to-right, presenting calories on the left side of food labels can help to reduce calorie intake by 16.31%. The distribution of calories within the menu can also affect the accuracy of recalled calories during food choices. Suppose an agent faces a menu consisting of multiple food items. If the agent is careful about what he eats, he will spend some amount of time examining each food item. He will try to memorize the properties of each examined item as he moves through different food products on the menu. The agent may revisit all (or some) of the food items on the menu before choosing his preferred item. Nevertheless, at the decision time, he will mostly rely on his recall of the calories he just (un)consciously tried to memorize. Choplin and Wedell (2014) tested how the recall process is impaired when the calorie distribution of the menu was positively and negatively skewed by introducing lower and higher calorie products, respectively. They report that the largest and smallest calorie values were recalled less in positively skewed distributions compared to negatively skewed distributions. Choplin and Wedell (2014)'s work implies that by adding a food item with an extremely large number of calories into the menu, the recalled or perceived calories of the other food products will be smaller compared to the case when the item is missing from the menu. Ellison et al. (2014b) find that compared to numeric calorie information, symbolic traffic light food labels are more effective in reducing calorie consumption. The parallel food labeling literature suggests that perceived and processed calorie information might be very different from the actual calorie amount shown on food labels. This information distortion can be very sensitive to the cues in the decision context. Our study follows this line of research and strives to disclose the behavioral underpinnings of the acquisition and processing of food calorie information. We hypothesize that when a consumer chooses from a food menu, the calorie distance between the food products affects his decision. Even when an economic agent faces a menu with multiple food products, his choice problem shrinks to the trade-off among a few alternatives. To keep it simple and identifiable, we use binary menus to study the impact of the calorie distance on healthy (low-calorie) food choices.

An important consideration in food choice and calorie intake is the behavior of food suppliers. Unfortunately, the reaction of restaurants to the calorie labeling laws is not clear (Bleich et al., 2017). Some initial studies report no significant changes in the nutritional and calorie content of menu items across targeted restaurants after the adoption of the law in 2008 (Namba et al., 2013; Deierlein et al., 2015). Namba et al. (2013) find that although the proportion of healthier food products has increased since 2008, the average calories of the studied menus stayed the same. This raises additional concerns about the "healthiness" of new food products considering the fact that average offered calories has not changed. Thus, based on initial findings, we can conclude that the calorie distance between new healthy items and conventional high-calorie food products have not changed significantly. Which according to our theoretical model and the results of our two experiments, may explain why calorie labeling laws have not been very effective.

3. Experiments

3.1. Lab experiment

We conducted two experiments to study the impact of calorie information and calorie distance on low-calorie food choices. The first experiment was a lab experiment conducted in the Summer of 2018. We employed a 3x2 between-subject design.[4] Subjects were recruited by a bulk email sent to all undergraduate students enrolled at a university located in the Southwestern United States. The email contained a sign-up link, and the main requirement was to abstain from eating and drinking for three hours before arriving to the lab.[5] The only exclusion criterion was having any known allergy and/or food and dietary restrictions. Upon arriving to the lab, subjects were randomly assigned to one of two experimental sessions: More Tempted and Less Tempted states. In the Less Tempted condition, subjects had to drink a protein shake (160 calories) before starting the experiment. In the More Tempted condition, subjects started the experiment without any food/beverage intake. Our assumption is that subjects who drink the protein shake are less hungry and hence less tempted compared to subjects who start the experiment without any calorie intake. In fact, our analyses show that in the More Tempted condition, on average, subjects reported more temptation to both high ($z = -1.32$, $p = 0.09$) and low-calorie ($z = -2.14$, $p = 0.02$) snacks compared to the Less Tempted condition.[6] This dimension helped us to understand the role of temptation in processing the calorie information and also to observe the moderation effect of visceral feelings in low-calorie food choices.

The experiment consisted of two treatments and one control. Subjects were randomly assigned to the treatments or to the control in the More and Less Tempted sessions. Subjects had to complete 40 food choices across 40 binary menus/trials. Before the experiment, subjects were informed that at the end of the study one of the trials would be randomly chosen, and they would have to consume their chosen product from the selected trial.[7] Since food choices were incentivized, meaning subjects had to eat their chosen product, it was in the best interest of subjects to choose the snack they actually wanted to eat. This procedure enables us to elicit subjects' true preferences by making possible deviations from their true preferences costly.

To control for brand effects and preferences for particular snack products, in each binary menu (i.e., in each trial), subjects were presented with a *regular* and a *reduced-calorie* version of the same snack. For example, in one of the choice menus, subjects had to choose either a regular Oreo or a reduced-fat Oreo. The serving sizes of alternatives were kept the same in order not to introduce a quantity difference between food snacks. Subjects were not shown nutritional contents of alternatives. Therefore, the calorie difference was the only dimension to compare snacks. Overall, each trial consisted of a binary-forced food choice problem.

In 16 (13) binary menus, the trade-off was along regular versus reduced-fat (reduced-sugar) products. The rest of the trials tested choice behavior without an explicit reference to either the sugar or fat dimension (for instance, regular vs. light yogurt). This aspect of the experiment helped us to observe differential behavioral approaches towards fat-intensive, sugar-intensive, and products where the source of the calorie reduction was undisclosed. Overall, in 20 trials, the relative calorie

[4] See Appendix A for details.

[5] We did not have any available non-intrusive method to test whether subjects complied to the fasting requirement or not. However, random assignment of subjects to the experimental conditions can mitigate uncontrolled and unmeasured differences in pre-experimental fasting. Previous studies also used random assignment to deal with uncontrolled fasting (e.g., Brown et al. (2009); Bushong et al. (2010)).

[6] Errors are clustered at the subject level.

[7] Subjects were required to eat only one serving size of the chosen product.

distance between products was less than or equal to 40 calories. In the rest of the trials, the calorie distance was over 40 calories.[8]

In the No Information condition, subjects were shown the food options in the original product packages without the table of nutrition details and any calorie information. Then, they had to choose one of the food snack alternatives. In the No Information condition, subjects were neither provided with the calorie information nor the calorie aspect of the food choice problems was salient. This helped us to capture the “raw human nature” before the introduction of calorie information. In the Accurate Information treatment, subjects were provided the calorie information of products, and they had to type the displayed calories into a box before indicating their choices. This feature was an important aspect of our design to make sure that subjects attended to and processed the accurate calorie information. Subjects had to choose their preferred products after typing the calorie information. This treatment allows us to study the effect of calorie information provided that consumers paid attention to the calorie product attribute. In the Homegrown Information treatment, subjects were asked to provide their *beliefs* about the calorie content of each product and type their beliefs into a box prior to making their food choice.[9] This part of the experiment helped us to observe the knowledge of consumers about the calorie content of food products in the absence of an external accurate information source.

The experimental sessions were scheduled from morning to evening hours. To minimize the effect of the time of the day, we randomized and balanced the number of More and Less Tempted sessions across all time slots. In each time slot, subjects were randomly assigned to the experimental conditions: No Information, Accurate Information, and Homegrown Information.[10]

After the food-choice part of the experiment, subjects were presented with each snack product on a separate screen and were asked to indicate how much temptation they experienced towards the product.[11] This stage was followed by a demographic survey. To check subjects’ compliance with the fasting requirement and also to test the effect of consuming the protein shake on the hunger level, we asked subjects to report their level of hunger prior to the experiment at the time of answering the final survey questions. According to Table A1 in Appendix A, we do not detect statistically significant differences in “entry hunger” (the hunger level before consuming the protein shake in the Less Tempted condition) levels across the experimental conditions. We see the opposite case in “exit hunger” levels which hints that subjects were indeed less hungry if they had to drink the protein shake before the experiment.[12] We observe that when subjects did not consume the protein shake, they report a higher level of hunger at the end of the study. Although these results are based on self-reported measures, they suggest that consuming the protein shake helped to reduce the hunger level of subjects. An OLS regression analysis in Appendix A shows that there is a significant and positive correlation between the level of hunger and the reported temptation to snack products. Therefore, we can conclude that consuming the shake indeed changed the hunger level and consequently affected the temptation towards products.

3.2. Lab in the field restaurant experiment

Our lab experiment was designed to reveal the effect of the calorie distance when consumers were explicitly directed to notice and process the calorie information (Accurate Information) or when they were asked to submit their beliefs about the calorie content of food products without any external help (Homegrown Information). Both in the Accurate and Homegrown Information conditions, subjects had to mentally engage with calorie information (in the form of processing the provided information or submitting their beliefs) and type the provided or believed calorie amounts into a box before choosing their preferred snacks. The control condition did not engage subjects with any mental or typing activities. The distribution of the calorie distance across menus had a mean of 46.7 calories, and it raised the question of the sensitivity of our results to higher magnitudes of calorie differences as it is usually the case in full meals.

We conducted a lab-in-the-field experiment at a local restaurant from a national chain to address the above-mentioned concerns and to test the robustness of our findings in a more realistic environment. Our restaurant experiment took place in late January, 2019. Subjects were recruited from the student body of the University and the local community. Subjects were required to abstain from eating and drinking three hours before arriving to the restaurant and have no known allergies or food restrictions. Prior to the experiment, subjects were informed that they would choose their preferred food from especially designed menus and would have to eat their randomly selected choices before leaving the restaurant. Thus, they were neither allowed to take their selected food products out of the restaurant nor were they permitted to share their food

---

[8] The distribution of the calorie distance across menus had the mean of 46.7 calories (Min=6, Max=190, st. dev.=45.48).

[9] We did not incentivize the elicitation of calorie beliefs on purpose. Monetary incentives would have pushed subjects to eliminate their biases and provide more accurate calorie estimates. However, that would not serve our research goals, as we wanted to observe whether consumers held systematic biases about the calorie contents of food products, and more importantly, whether they acted in line with their biases. Moreover, not incentivizing calorie guesses also helps us to align our design to a real-life situation where subjects have biases in their calorie beliefs, and they (mostly) act with those biases.

[10] Table A1 in Appendix A shows the demographic profile of subjects in each experimental condition. The comparison of conditions across different aspects of demographic profile reveals that the randomization was successful.

[11] Subjects used a 9-point Likert scale to report their temptation level (1 - “Not at all; 9 - “Extremely”.)

[12] Unpaired Wilcoxon tests also support the findings in Table A1. In the Less Tempted condition, the exit and entry hunger levels were not statistically different ($z = -0.90$, $p = 0.18$). However, in the More Tempted Condition, the exit and entry hunger levels were statistically different ($z = -5.58$, $p < 0.01$).

with others. No participation reward was promised besides covering the food expenses. Thus, subjects had incentives to arrive hungry to enjoy their selected food items in the diner at the expense of the experimenters.[13]

We ran sessions from 12:00 pm until 8:00 pm on two consecutive Fridays, Saturdays, and Sundays. We installed two computer stations with eye-trackers in the backroom of the diner. We could only accommodate two subjects per half-an-hour slot. After arriving at the diner, subjects were briefed about the rules that were explicitly spelled out in the recruitment email, and they were provided with informed consent forms. After reading and signing the consent forms, subjects were randomly assigned either to the No Information or Accurate Information conditions. In both conditions, subjects went through 86 binary menus and selected their preferred meal in each menu. In the No Information condition, subjects were presented only with the descriptions of meals. However, in the Accurate Information condition they were also provided with calorie information below the food descriptions.

Similar to the lab experiment, to control for food preferences, subjects were offered the same or similar meals in each binary menu. We customized the ingredients and the side dishes of meals to exogeneously manipulate the magnitude of the calorie distance between the food products.[14]

Once subjects chose their meals in each menu and completed all 86 trials, we randomly selected one trial as the binding menu.[15] Subjects were informed about the randomly selected menu and shown their choice in that particular menu. In the No Information condition, subjects only saw the description of their selected meal (it was exactly the same description they had seen while indicating their choices in 86 trials). However, in the Accurate Information condition, subjects saw the descriptions and the calorie information of their chosen meal (similar to the previous 86 trials in that condition).

Then, subjects were provided with a beverage menu without the calorie information in the No Information, and with the calorie information in the Accurate Information condition. After choosing their preferred beverage, subjects were also provided with a dessert menu with and without the calorie information in the Accurate and No Information conditions, respectively. This part of the experiment was designed to observe whether subjects engage in any "calorie budgeting." We also used eye-tracking technology in our experiments. Appendix B presents the details regarding the eye-tracking data-collection process.

4. Theoretical model

4.1. Modeling strategy

We choose menu-dependent preferences and axiomatic menu choices as our modeling framework (Gul and Pesendorfer, 2001; Noor, 2007; 2011). We do not directly test self-control models a la Gul and Pesendorfer (2001) since employed experimental choice tasks are binary menus without *set betweenness* (i.e., a combined menu including both alternatives). Eliciting preferences over menus is necessary for eliciting the demand for commitment to the low-tempting choice alternative when choice situations are comprised of two or more periods. The set betweenness axiom of Gul and Pesendorfer (2001) offers one possible framework for understanding the demand for commitment. We do not employ *set betweenness* as the temporal choice consistency is not part of our investigations. However, our post-experimental surveys provide evidence that the main measure of interest–*calorie distance*–is a plausible proxy for *temptation*. In this regard, our model is nested in standard utility maximization models with a specific utility function that can also capture menu-dependent visceral feelings affecting food decisions.

Our primary modeling motivation is that the utility derived from choice attributes is sensitive to the choice context (i.e., choices are menu-dependent). For instance, the utility of choosing an apple when the alternative is an orange is different compared to the choice situation when the alternative is a chocolate brownie (Noor and Takeoka, 2010). In the latter case, the utility of the apple is significantly discounted by the most tempting option (chocolate brownie) in the menu. Gul and Pesendorfer (2001) show that the decrease in derived utilities due to the unchosen item in the menu can be formulated by explicitly modeling *normative* and *temptation* utilities with *complete* and *transitive* preferences. Having temptation utility in the model also enables us to model the self-control cost arising from visceral feelings pertinent to food choice environments (Loewenstein, 2000). In a food choice setting, this modeling strategy is especially suitable to reduce the number of choice attributes focusing on the important ones that are measurable, relatively more accessible, and targeted by different health policies. This aspect of our modeling strategy paves a way to represent temptation utility differences with calorie differences that were the primary target of calorie labeling laws. Our framework is also helpful in incorporating the role of revealing the calorie information and its salience in food choices.

One can also develop a simple model following the Random Utility Model (RUM) framework and estimate the impact of calorie differences in the menu on food choices.[16] In Appendix A, we show that our main results can also be replicated with

[13] All subjects complied with the rules.

[14] The distribution of the calorie distance across menus had the mean of 435.87 calories (Min=30, Max=1320, st. dev.=322.71). The list of food items and their calories are reported in Appendix A.

[15] Since the number of trials is high it can trigger a fatigue effect. Note the presentation order of stimuli (binary menus) was randomized for each subject. In Appendix A, we control the presentation order of each menu and show that although the fatigue effect is marginally significant, it has a very negligible negative effect on the probability of choosing low-calorie choices. More importantly, controlling the possible fatigue effect does not change our main results.

[16] We are grateful to an anonymous reviewer for pointing this out.

a general RUM framework using a random parameter binary logit estimation. However, our model choice has crucial merit in explaining our treatment conditions in the context of menu-dependent preferences and visceral feelings. Specifically, our modeling framework intuitively explains the calorie distance measure's role as a valid measure for temptation utility differences and self-control costs and the effect of the salience of the calorie information on food choices. Overall, our model is nested in standard expected utility models without excluding the general RUM framework and enables interpreting our results in the context of menu-specific self-control cost and temptation.

4.2. Temptation, self-control cost and salience of information

Let $A = \{a_1, a_2, \dots, a_n\}$ be a set of food items. Since agents choose from a menu with exactly two items, define $X = [A]^2$. Thus, X is the set of subsets of A with exactly two elements. The agent receives utility from consuming any $a \in A$. We denote this as $u(a)$ and refer to it as the normative utility of the item a. We want to assess an agent's decision when facing a menu with a low and a high-calorie alternative. Then, if $x = \{a, b\}$ and a has lower number of calories compared to b, $u(a) > u(b)$. In other words, we use normative utility to depict preferences of the agent from an objective perspective. Additionally, food choices generate temptation and, therefore, economic agents incur self-control costs in trying to resist temptation. Thus, we do not expect agents to always choose the low-calorie item in a real-world setting. As such, we argue that the agent can be tempted into choosing the high-calorie alternative (Gul and Pesendorfer, 2001; Noor and Takeoka, 2010; 2015). For any $a \in A$, we use $v(a)$ to depict item a's temptational utility. Temptation cannot be directly observed and we need to find a plausible indicator/proxy to measure it. In the Results section, our foundational result shows that the calorie distance between menu items is a plausible proxy to measure and study temptation. Therefore, our agent derives higher temptational utility from the high-calorie alternative in the binary menu. Following Noor and Takeoka (2015, 2010), for any $x \in X$, the agent's decision problem can be represented as:

$$W(x) = \max_{a \in x} \left[u(a) - \psi\left(\max_{b \in x} v(b)\right)\left(\max_{b \in x} v(b) - v(a)\right)\right] \tag{1}$$

where $\psi(\cdot) > 0$ is a weakly increasing continuous function. The second term in (1) is the self-control cost the agent faces by resisting the temptation of choosing the high-calorie item. This formulation shows that the agent has to choose the high-calorie item to lower the cost of resisting temptation. The function $\psi(\cdot)$ depicts the importance an agent places on his self-control cost and can be considered as its salience. For any $x \in X$, let $C(x)$ be the choice correspondence induced by (1), such that, $C(x) = \text{argmax}_{a \in x}[u(a) + \psi(\max_{b \in x} v(b))v(a)]$. Consider any $x \in X$ with $x = \{a, b\}$ such that $u(a) > u(b)$ and $v(a) < v(b)$. Then, $C(x) = \{a\}$ if $u(a) - u(b) > \psi(v(b))[v(b) - v(a)]$. So, we have:

$$\begin{aligned} \Pr[C(x) = \{a\}] &= \Pr[u(a) - u(b) - \psi(v(b))[v(b) - v(a)] + \varepsilon > 0] \\ &= F[u(a) - u(b) - \psi(v(b))[v(b) - v(a)]] \end{aligned} \tag{2}$$

where we assume that $\varepsilon \sim F$ is symmetric around zero. Additionally, we assume that F is an increasing function. Since ε is symmetric around zero, $E(\varepsilon) = 0$. The introduction of the random variable ε allows some deviations from the decision problem of (1) owing to each agent's preferences but suggests that, on average, observed choices should be in accordance with (1).

Definition 1. (*Normatively identical menus*) Any $x, x' \in X$, with $x = \{a, b\}$ and $x' = \{a', b'\}$ such that $u(a) > u(b)$, $v(a) < v(b)$, $u(a') > u(b')$ and $v(a') < v(b')$, are said to be *normatively identical* if $u(a) = u(a')$ and $u(b) = u(b')$.

Definition 2. (*Higher temptation difference*) For any $x, x' \in X$, with $x = \{a, b\}$ and $x' = \{a', b'\}$ such that $u(a) > u(b)$, $v(a) < v(b)$, $u(a') > u(b')$ and $v(a') < v(b')$, x is said to have *higher temptation difference* than x' if $v(b) \geq v(b')$ and $v(b) - v(a) > v(b') - v(a')$.

The next proposition shows that, under certain circumstances, an increase in temptation utility distance increases the probability with which the high-calorie alternative is chosen over the low-calorie alternative.

Proposition 1. For *normatively identical menus*, the menu with *higher temptation difference* has lower probability of the low-calorie item chosen.

Proof: See Appendix C1

Quantifying temptation utility is quite challenging. Moreover, temptation utility is also essential in validating our model. In Appendix A, we show that there is positive correlation between the self-reported temptation difference and the calorie distance. Therefore, we employ the calorie distance between snacks in menus as a proxy for temptation difference. Establishing this empirical relationship enables us to state the first hypothesis of the model:

Hypothesis 1: Subjects will be less likely to choose low-calorie snacks as the calorie distance between the alternatives becomes greater.

The utility representation in Eq. (1) does not consider that temptation utilities and salience might vary across different states in a real-world setting. It is possible that certain circumstances make agents more concerned with their health and, as such, they might become less concerned with their self-control costs. Let $\tau \in \{0, 1\}$. We say that the calorie content of snacks is *salient* if $\tau = 1$ and *not-salient* if $\tau = 0$. We would expect the agent to give less importance to his self-control costs when the calorie content of food alternatives is *salient*. This can be depicted as $\psi(\cdot; \tau = 0) > \psi(\cdot; \tau = 1)$.

On the other hand, circumstances can arise in which the agent is more susceptible to temptation. For instance, if a person is hungry, we would expect him to be more easily influenced into consuming a high-calorie item. Let $\lambda \in \{0, 1\}$. We say an agent is *hungry* if $\lambda = 1$ and *non-hungry* if $\lambda = 0$. We would expect a *hungry* or *non-satiated* agent to receive more temptation utility from each item: $v(\cdot; \lambda = 1) > v(\cdot; \lambda = 0)$.[17] Additionally, we assume that a *non-satiated* agent faces at least as much self-control cost compared to a *satiated* agent which makes it harder for the former to exercise self-control. This suggests that for any $x \in X$, we have the following:

$$\max_{b \in x} v(b; \lambda = 1) - v(a; \lambda = 1) \geq \max_{b \in x} v(b; \lambda = 0) - v(a; \lambda = 0) \ \forall a \in x$$

Considering these particular states, the representation of (1) can be rewritten as follows:

$$W(x; \tau, \lambda) = \max_{a \in x} \left[u(a) - \psi\left(\max_{b \in x} v(b; \lambda); \tau \right) \left(\max_{b \in x} v(b; \lambda) - v(a; \lambda) \right) \right] \tag{3}$$

The choice correspondence associated with the problem presented in (3) can be given as:

$$C(x; \tau, \lambda) = \text{argmax}_{a \in x} \left[u(a) + \psi\left(\max_{b \in x} v(b; \lambda); \tau \right) v(a; \lambda) \right]$$

Then, we have:

$$\begin{aligned} \Pr[C(x; \tau, \lambda) = \{a\}] &= \Pr[u(a) - u(b) - \psi(v(b; \lambda); \tau)[v(b; \lambda) - v(a; \lambda)] + \varepsilon > 0] \\ &= F[u(a) - u(b) - \psi(v(b; \lambda); \tau)\{v(b; \lambda) - v(a; \lambda)\}] \end{aligned} \tag{4}$$

Proposition 2. For the same menus, if the calorie content of products is *salient*, agents will choose the low-calorie menu item with a higher probability than agents who are in the choice-context where the salience of food information is missing.

Proof: See Appendix C2

In the Homegrown and Accurate Information conditions, the number of calories in food alternatives was salient for subjects. The only difference was that in the Homegrown condition, subjects had to rely on their own calorie estimates. However, in the Accurate Information condition subjects were provided with the accurate calorie information. Proposition 2 enables us to state the following hypothesis:

Hypothesis 2: Subjects in the Homegrown and Accurate Information conditions will be more likely to choose low-calorie snacks compared to the No Information condition.

Proposition 3. For the same menus, *satiated* agents choose the healthy item with at least as much probability as *non-satiated* agents.

Proof: See Appendix C3

Recall that, in the Less Tempted condition, subjects drank a protein shake (160 Calories) before making food decisions. The average number of calories in low and high-calorie snacks was 85.88 and 132.6, respectively. Therefore, we assume that subjects who drank the protein shake were feeling less hungry compared to the subjects who started the study without any beverage intake. Table A1 also shows that at the end of the experiment, subjects who drank the protein shake were on average less hungry compared to subjects who started the study without any calorie intake. Based on Proposition 3, we can state the following hypothesis:

Hypothesis 3: Subjects in the Less Tempted condition will be more likely to choose low-calorie snacks.

4.3. Information estimation

Consider any $x \in X$ such that $x = \{a, b\}$ where $u(a) > u(b)$ and $v(a; \lambda) < v(b; \lambda)$ for $\lambda \in \{0, 1\}$. If normative utility difference is sufficiently high, the agent chooses menu item a otherwise he chooses menu item b. However, in certain situations, an agent may not actually have accurate information regarding his temptation utilities. In such circumstances, the agent might base his decisions on his estimated values of temptation utilities. We consider three potential situations when the agent acts in accordance with his own estimates of temptation differences: *Unbiased temptation difference, Over-estimated temptation difference*, and *Under-estimated temptation difference*. When the agent holds unbiased believes about the temptation differences, he acts as if he has the calorie information. Then, we should expect that, on average, the agent chooses the low-calorie item with the same probability as an agent with complete information. If the agent over-estimates (under-estimates) the temptation utility differences, then, on average, he chooses the low-calorie menu item with lower (higher) probability as compared to an agent with complete information. Our discussions yield the following hypotheses:

Hypothesis 4:

4.1. When the estimated and the true calorie distances are the same, there should be no difference in choices of the Homegrown and Accurate Information conditions,

4.2. When the estimated calorie distances are greater than the true calorie distance, agents in the Homegrown Information condition choose low calorie item with lower probability compared to agents in the Accurate Information condition, and

[17] In Appendix A, we show that reported hunger levels are positively correlated with temptation ratings of food snacks in the lab experiment. Therefore, the employed functional forms are consistent with the evidence we observe in our data. However, future studies can also consider incorporating λ in $\psi(.)$ if hunger levels affect the relative weights of temptational and normative utilities as well.

Table 1
Low-calorie choice tendency and the temptation ranking distance (lab experiment).

	(1)	(2)	(Sugar-subsample)	(Fat-subsample)	(Undisclosed-subsample)
(Intercept)	0.00***	0.00***	0.00***	0.00***	0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Temptational distance	−0.05***	−0.05***	−0.05***	−0.08***	−0.04***
	(0.01)	(0.01)	(−0.05)	(−0.08)	(−0.04)
Male		−0.12***	−0.09**	−0.14***	−0.11***
		(0.03)	(−0.09)	(−0.14)	(−0.11)
BMI		0.01*	0.01	0.01**	0.00
		(0.00)	(0.01)	(0.01)	(0.00)
High Income dummy (>60,000 USD)		−0.02	0.01	−0.06	0.00
		(0.03)	(0.01)	(−0.06)	(0.00)
AIC	11616.35	10773.57	3465.54	4231.66	3024.46
BIC	11630.48	10808.58	3494.93	4262.09	3053.02
Log Likelihood	−5806.18	−5381.78	−1727.77	−2110.83	−1507.23
Deviance	11612.35	10763.57	3455.54	4221.66	3014.46
Num. obs.	8640	8120	2639	3248	2233

$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. *Note:* The table shows the results of the Logit regression analysis across all experimental conditions with clustering at the subject level. The dependent variable is a binary measure, and it is "1" when the subject chooses the low-calorie alternative in the binary menu. The temptational distance variable is the temptation ranking difference between the alternatives. The clustering helps to account the possible serial correlation among repeated measures.

4.3. When the estimated calorie distances are less than the true calorie distance, agents in the Homegrown Information condition choose low calorie item with higher probability compared to agents in the Accurate Information condition.[18]

5. Results

5.1. The calorie distance affects the temptational utility difference (Foundational Result)

In our theoretical model, we show that food choices are mainly driven by the relative temptation utilities of the menu alternatives. Our first proposition states that subjects will incur in higher self-control costs as the temptation distance (or temptational utility difference) between the two alternatives increases. Since temptation cannot be directly detected, we need an additional tool/proxy to measure it. Finding a plausible proxy for temptation also enables us to exogenously manipulate it and study its causal impact on food choices. In the lab study, subjects report their temptation levels to each product separately after the main part of the study using a 9-point Likert scale. Table 1 shows that an increase in the temptational utility distance (i.e., the reported temptation level difference) is associated with a lower likelihood of choosing the low-calorie alternative in the lab study. According to Table 1, a one-point increase in the temptational utility ranking difference reduces the probability of choosing the low-calorie snacks by 5 percentage points (p.p.).

Moreover, Table 2 presents evidence that there is a significant positive relationship between calorie distance and temptation distance, and even after controlling for observables this relationship still holds. Thus, it justifies using the calorie distance variable as a proxy measure for the temptational utility difference.

Although pinning down the source of temptation is not part of our primary investigation in this study, it is intuitive to predict a positive relationship between the perceived taste of food and temptation feelings towards them. Some neuroeconomic experiments associate"palatable" food with specific reward systems, which would provide some neurobiological support to this notion (de Macedo et al., 2016; Alonso-Alonso et al., 2015). Although not specifically referring to calories, previous studies report that consumers have a tradeoff between nutritional information and taste (Berning et al., 2011; Wardle and Huon, 2000; Drichoutis et al., 2006). The implication is that when consumers compare two foods, they perceive the nutrition and taste as two opposing factors. This is likely to affect the temptation and self-control for the food choice.[19]

One can argue that subjects might choose high-calorie snacks to obtain more nutritional content. Thus, choosing the high-calorie alternative does not necessarily mean succumbing to temptation. As mentioned in the *Experiment* section, subjects did not have access to the nutritional panel information. Subjects were only informed that in some choices the calorie trade-off was along the sugar dimension (e.g., Jellow Strawberry vs Sugar Free Jellow Strawberry) or fat dimension (e.g., Colby Jack vs Reduced Fat Colby Jack). Moreover, in some choice sets, the trade-off dimension was not disclosed (e.g., Yoplait cherry vs Yoplait cherry light). Table 1 shows that a one point increase in the temptational utility difference is associated with 5 p.p. and 8 p.p. reduction in the probability of choosing low-calorie snacks in the Sugar-subsample (where the trade-off was along the sugar dimension) and Fat-subsample (where the trade-off was along the fat dimension), respectively.

[18] It should be noted that we still use $\psi(\max_{b\in x} v(b;\lambda);\tau)$ in the choice rule for Hypotheses 2, 3, and 4 in accordance with our general modeling framework inspired by Noor and Takeoka (2010, 2015). However, Hypotheses 2, 3, and 4 do not hinge on this functional form. One can drive those hypotheses using $\psi(\lambda;\tau)$ if $\psi(\lambda;\tau) > 0$, $\psi(\lambda=1;\tau) > \psi(\lambda=0;\tau)$, and $\psi(\lambda;\tau=0) > \psi(\lambda;\tau=1)$.

[19] Our additional MTurk study validates this study (Please see Appendix A).

Table 2
Calorie Distance and Temptation in the lab experiment.

	Dependent variable: Temptation Distance	
	(1)	(2)
Calorie distance	0.230***	0.190**
	(0.084)	(0.087)
Male		0.245*
		(0.129)
BMI		0.001
		(0.014)
High Income (dummy)(>60,000 USD)		0.042
		(0.131)
Constant	0.502***	0.387
	(0.068)	(0.361)
Observations	8,630	8,110
R^2	0.003	0.005
Adjusted R^2	0.003	0.005
Residual Std. Error	2.209 (df = 8628)	2.202 (df = 8105)

$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. *Note:* The table shows the results of OLS regression analysis and errors were clustered on subject level. The clustering helps to account the possible serial correlation among repeated measures. Calorie distance variable is the actual (except Homegrown condition) calorie distance between the alternatives and normalized by 100 calories. The dependent variable is the difference between self-reported temptation scores of high and low-calorie snacks.

However, when the trade-off dimension was undisclosed, a one-point increase in the temptational utility difference reduced the likelihood of low-calorie choices by 4 p.p. These results suggest that the alternative explanation that subjects could have chosen high-calorie alternatives because of the nutritional content is not substantiated by our data. Furthermore, the fact that the negative effect of the temptational distance on low-calorie choices is more pronounced for sugar- and fat-intensive products, validates our assumption that a larger calorie difference from higher sugar or fat content is related to increased self-control costs. However, the temptational utility is an endogenous measure and drawing a causal relationship based on the temptational utility ranking is not feasible. Therefore, our data is well-suited to study the role of the self-control cost (i.e., temptational utility difference) with the help of exogenously manipulated calorie differences in food choices.

5.2. The effect of the calorie distance on low-calorie choices (Result 1)

Based on our model, we predict that the calorie distance between the alternatives will be a strong factor in explaining low-calorie choices. *Hypothesis 1* states that the probability of low-calorie choices depends on the calorie distance between the snacks, and an increase in the distance decreases the probability of choosing low-calorie alternatives.

We start our analysis focusing on the lab experiment results. Table 3 validates *Hypothesis 1* and shows that an increase in the calorie distance between the choice alternatives reduces the probability of choosing the low-calorie snack in the lab experiment. Table 3 column 5 displays that after controlling for demographic variables, a 100-calorie increase in the calorie distance decreases the probability of choosing the low-calorie snack by 3 p.p. This effect becomes larger and reaches 10 p.p. as we control for the experimental conditions and their interactions with the calorie distance in Table 3 column 6. Table 3 column 7 shows that when we include the interaction of the experimental conditions with the More Tempted state, the results are robust and do not change. The Akaike Information Criterion (AIC) has its lowest value in Table 3 column 7. Therefore, it shows that the model analyzed in the last column better fits our data compared to the model specifications in other columns of Table 3. The documented effect of the calorie distance on the low-calorie choice probability is a causal relationship, as we exogenously varied the relative difference between the calorie contents of the alternatives.

The results of the restaurant experiment also confirm *Hypothesis 1*. Table 4 column 5 shows that a 100-calorie increase in the calorie distance reduces the probability of choosing low-calorie foods by 2 p.p. This effect is robust across different model specifications in Table 4.

Our first set of results from both the lab and the restaurant experiments confirms *Hypothesis 1* and shows that the success of self-control acts mainly depends on the choice context or the menus in food decision-making. This result also provides strong evidence that models on menu-dependent preferences are very promising in explaining the empirical irregularities in previous research.

The analysis of the interaction terms in Table 3 column 7 shows that the effect of the calorie distance on the probability of low-calorie choices can be reversed if the calorie content of the food products is salient. A 100-calorie increase in the calorie distance increases the probability of choosing the low-calorie snack by 12 p.p and 9 p.p in the Accurate and Homegrown Conditions, respectively. It is also interesting that the Accurate and Homegrown Information conditions do not affect low-calorie choices directly, but only through the calorie distance variable. A 100-calorie increase in the distance reduces

Table 3
Low-calorie choice tendency and the calorie distance (lab experiment).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(Intercept)	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Male	−0.11***	−0.11***	−0.11***	−0.10***	−0.11***	−0.11***	−0.10***
	(0.01)	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)
BMI	0.01***	0.01*	0.01	0.01*	0.01*	0.01*	0.01*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
High Income dummy (>60,000 USD)	−0.02**	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02
	(0.01)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Accurate Information		0.03		−0.00		−0.03	−0.05
		(0.04)		(0.06)		(0.04)	(0.06)
Homegrown Information		−0.01		0.02		−0.05	−0.02
		(0.04)		(0.06)		(0.05)	(0.06)
More Tempted			−0.01	−0.01		−0.01	−0.01
			(0.03)	(0.05)		(0.04)	(0.06)
More Tempted*Accurate Information				0.06			0.06
				(0.08)			(0.08)
More Tempted*Homegrown Information				−0.06			−0.06
				(0.08)			(0.08)
Calorie distance					−0.03*	−0.10***	−0.10***
					(0.02)	(0.03)	(0.03)
Calorie distance*More Tempted						−0.01	−0.01
						(0.04)	(0.04)
Calorie distance*Accurate Information						0.12***	0.12***
						(0.04)	(0.04)
Calorie distance*Homegrown Information						0.09**	0.09**
						(0.04)	(0.04)
AIC	11020.64	11017.70	11021.42	11003.38	10998.42	10986.35	10971.40
BIC	11048.64	11059.71	11056.43	11066.40	11033.42	11063.36	11062.41
Log Likelihood	−5506.32	−5502.85	−5505.71	−5492.69	−5494.21	−5482.17	−5472.70
Deviance	11012.64	11005.70	11011.42	10985.38	10988.42	10964.35	10945.40
Num. obs.	8120	8120	8120	8120	8110	8110	8110

$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. *Note:* The table shows the results of the Logit regression analysis across all experimental conditions with clustering at the subject level. The dependent variable is a binary measure, and it is "1" when the subject chooses the low-calorie alternative in the binary menu. The clustering helps to account the possible serial correlation among repeated measures. The calorie distance variable is the actual calorie distance between the alternatives in the Accurate Information and No Information conditions. However, the calorie distance variable includes estimated calories by subjects in the Homegrown Information condition, since subjects acted on their believes in this condition. The calorie distance variable is normalized by 100 calories. Thus, the marginal effect shown in the table indicates the probability change due to a 100 calorie increase in the calorie distance variable.

the probability of low-calorie choices because of incurred self-control costs, but it also increases the same probability due to the salience of the calorie content. However, we do not detect a significant interaction effect of the calorie distance and the Accurate Information condition in the restaurant experiment.

The interaction effects necessitate average marginal effect analysis to reveal the "net effect" of the calorie distance on the probability of choosing the low-calorie food. Fig. 1 panels (a) and (b) show the average marginal effect of the calorie distance variable on the probability of low-calorie choices in the lab and restaurant experiments, respectively. Fig. 1 panel (a) shows that the average marginal effect of the calorie distance is around 3 p.p in the lab experiment. Similarly, Fig. 1, panel (b) reports that the average marginal effect of the distance is around 2 p.p. in the restaurant experiment. Both experiments confirm *Hypothesis 1* and demonstrate that an increase in the calorie distance burdens agents with self-control cost and eventually decreases the probability of choosing low-calorie foods.

We observe that the demographic profile of subjects is a non-trivial determinant of their food choices in the lab experiment. According to Table 3 column 7, being a male on average reduces the probability of choosing the low-calorie food item by 10 p.p compared to females, and this result is robust across all considered models. Interestingly, higher BMI is associated with more frequent low-calorie choices. However, the marginal effect of BMI is 1 p.p. Table 3 demonstrates that income does not explain food choices in our sample. Table 4 reports that there is no significant relationship between demographic control variables and the probability of choosing low-calorie foods in the restaurant experiment. Overall, the relationship of demographic control variables with the outcome variable should be interpreted as correlation, since these variables are endogenous.

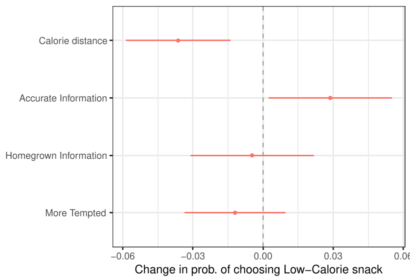
5.3. The effect of the salience of the calorie content of food products on low-calorie choices (Result 2)

Proposition 2 shows that consumers will be more likely to choose low-calorie snacks if the calorie content of food products is salient. In our model, we show that salience of the calorie content reduces the severity of the experienced menu dependent self-control costs. Therefore, our model predicts that subjects will be willing to incur the self-control cost and

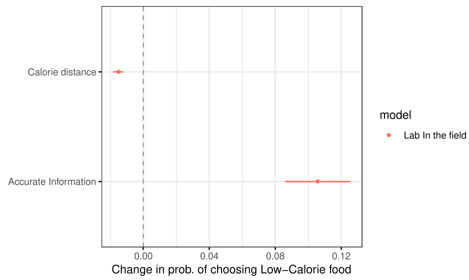
Table 4
Low-calorie choice tendency and the calorie distance (lab in the field experiment) .

	(1)	(2)	(3)	(4)	(5)
(Intercept)	0.00***	0.00***	0.00***	0.00***	0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Male	−0.04***	−0.04	−0.04	−0.04	−0.04
	(0.01)	(0.04)	(0.03)	(0.03)	(0.03)
BMI	−0.00***	−0.00	−0.00	−0.00	−0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
High Income dummy (>60,000 USD)	0.07***	0.07*	0.06	0.06	0.06
	(0.01)	(0.04)	(0.04)	(0.04)	(0.04)
Calorie distance		−0.02***		−0.02***	−0.02***
		(0.00)		(0.00)	(0.00)
Accurate Information			0.11***	0.11***	0.09***
			(0.03)	(0.03)	(0.03)
Calorie distance*Accurate Information					0.00
					(0.01)
AIC	13221.41	13131.86	13116.26	13025.68	13026.21
BIC	13250.10	13167.72	13152.13	13068.72	13076.42
Log Likelihood	−6606.71	−6560.93	−6553.13	−6506.84	−6506.10
Deviance	13213.41	13121.86	13106.26	13013.68	13012.21
Num. obs.	9632	9632	9632	9632	9632

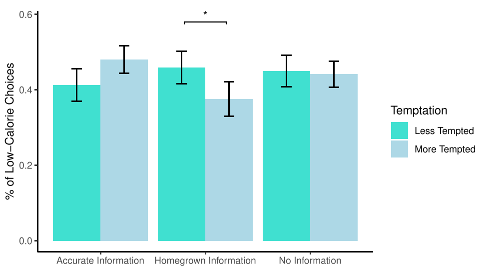
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. *Note:* This table displays the analysis of choices in the restaurant setting. The table shows the results of the Logit regression analysis across all experimental conditions with clustering at the subject level. The dependent variable is a binary measure, and it is "1" when the subject chooses the low-calorie alternative in the binary menu. The clustering helps to account the possible serial correlation among repeated measures. Calorie distance variable is the actual calorie distance between the alternatives and normalized by 100 calories. Thus, the marginal effect shown in the table indicates the probability change due to a 100 calorie increase in Calorie distance variable.



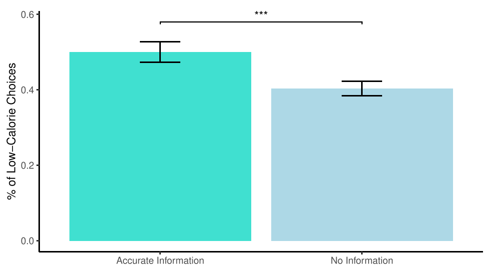
(a) The analysis of the average marginal effect of the calorie distance on low-calorie choices (lab experiment)



(b) The analysis of the average marginal effect of calorie distance on low-calorie choices (lab in the field experiment)



(c) Low-calorie choices across all experimental conditions (lab experiment)



(d) Low-calorie choices across all experimental conditions (lab in the field experiment)

Fig. 1. Low Calorie Choices across experimental conditions.

still will be more likely to choose low-calorie foods in the Homegrown and Accurate Information conditions of the lab experiment and in the Accurate Information condition of the restaurant experiment. *Hypothesis 2* states that subjects will be more inclined to choose low-calorie alternatives if the calorie content of food products is salient.

Table 3 column 2 reports the results of logit regression analyses with dummies for experimental conditions and with demographic controls. We observe that the effect of the salience of the calorie content of food products is not significant in the lab experiment. Our model with dummies for the Homegrown Information and Accurate Information conditions and with demographic control variables in column 2 robustly show that the effect of the salience of the calorie content of snacks on low-calorie choices is null in the lab experiment. However, as discussed above, Table 3 column 7 shows that when the calorie information is salient, an increase in the calorie distance also increases the probability of low-calorie choices. It seems the salience of calorie information affects choice outcomes mainly through the calorie distance in the lab experiment. Therefore, we have to consider the average marginal effect of salience in the lab experiment. Fig. 1 panel (a) shows that the Accurate Information condition has around 3 p.p average marginal effect on the probability of choosing low-calorie foods. The Homegrown Information condition has a null effect on low-calorie choices. Thus, we partially confirm *Hypothesis 2* in the lab experiment and show that only the Accurate information condition has an average marginal effect on low-calorie choices.

Following a similar line of analyses for the restaurant experiment in Table 4 reveals that the Accurate Information condition increases the probability of choosing low-calorie foods by 9 p.p. Fig. 1 panels (c) and (d) show that the effect of the Accurate Calorie Information is much stronger in the restaurant experiment than in the lab experiment. Fig. 1 panel (b) shows that the salience of the calorie information increases the probability of choosing low-calorie foods by 11 p.p in the restaurant experiment.

Overall, we confirm that the salience or the existence of the accurate calorie information *causally* increases low-calorie choices, and this effect is in the range of 3–11 p.p., depending on the food types and environment. It should be noted that the prediction of *Hypothesis 2* is the primary motivation behind calorie labeling laws. As discussed in the Literature Review section, the effect of calorie information treatments is inconclusive in previous related studies (Fernandes et al., 2016). In this article, we also show that the salience of the calorie content in decision environment has a non-uniform effect on food choices. We find a marginally significant and positive effect of calorie salience on low-calorie choices in the lab experiment and this effect is mediated by the calorie distance. Our restaurant experiment shows that the effect of information salience is around 11 p.p Our results are close to what Cawley et al. (2018) report in a recent study. Cawley et al. (2018) also find that showing consumers calorie information reduces the amount of ordered calories by 3 p.p. In this study, we show that the effect of the salience of the calorie content of food products might be very small in some environments, and this effect can be observed only by explicitly modeling menu-dependent self-control costs. This finding further supports the importance of modeling menu-dependent self-control costs in understanding the effect of calorie information on food choices.

5.4. The effect of temptation on low-calorie choices (Result 3)

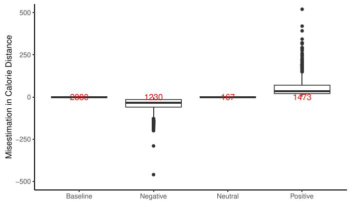
Proposition 3 shows that being in the hungry state reduces the probability of low-calorie choices. Our model shows that being hungry increases the effect of the temptation distance between food products and consequently imposes more self-control costs on decision-makers. *Hypothesis 3* states that subjects will be less likely to choose low-calorie snacks if they feel more hungry.

Figure 1 panel (c) shows the percentage of low-calorie snack choices across experimental conditions in the lab experiment. It can be observed that being more and less tempted has a marginal impact on the percentage of low-calorie choices only in the *Homegrown Information* condition ($z = -1.35, p = 0.09$). In other experimental conditions, if we compare more and less tempted states, we do not detect any significant differences in food choices. The regression analysis depicted in Table 3 column 3 shows that we do not detect any significant differential impact of the More Tempted state on low-calorie choices compared to the Less Tempted state. The analysis of the average marginal effects in Fig. 1 panel (a) also confirms our previous results. Thus, we show that being in the Less and More Tempted states turns out to be ineffective in reducing calorie intake. In fact, it has recently been shown that the relationship between sugar intake and self-control resources is inconclusive (Vadillo et al., 2016). We confirm this finding by demonstrating that drinking a protein shake does not have a significant impact on food choices.

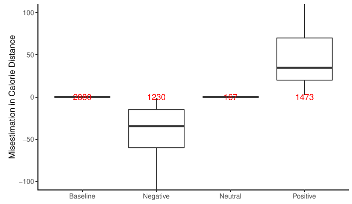
5.5. The impact of the bias in calorie estimates on food choices (Result 4)

Until this point, we have shown that the calorie information itself does impact low-calorie choices, but specificities of menus mediate this effect in the lab experiment. We also have shown that the calorie distance between the alternatives is important in food choices and can mediate the effect of calorie information.

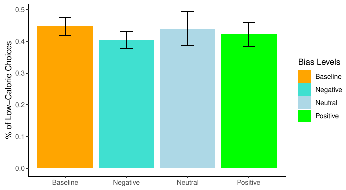
The Homegrown Information condition in the lab experiment helps us to identify one of the plausible channels through which the effect of the calorie distance can be transmitted to food choice outcomes. If the calorie distance is very closely related to temptation (which is shown in Appendix A), then its effect on the bias in calorie estimates can help us to understand the source of behavioral anomalies in food choices. In our model, and consequently in *Hypothesis 4*, we predict that upward biases in the belief estimates of the calorie distance between the alternatives will reduce the probability of low-calorie choices. The rationale of this prediction is that if subjects overestimate the distance, they also overrate the foregone



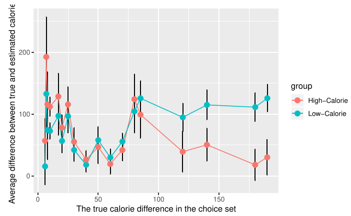
(a) "Average misestimation of calorie distance". This is the combination of the observations in Accurate and the Homegrown Information conditions. In the panel (b) we focus on the observations missestimations in the range of (-100,100).



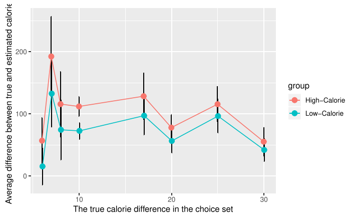
(b) "Average misestimation of calorie distance. This is the same figure depicted in panel (a). In this graph, to give e better sense about the means of the distributions, we focus on (-100, 100) range of misestimations, which represent 94% of the data."



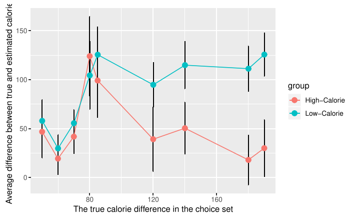
(c) "categories of misestimation of calorie distance and low-calorie choices"



(d) "Average misestimation of individual product calories"



(e) "Average misestimation of individual product calories in small (less than 40) calorie distance menus



(f) "Average misestimation of individual product calories in large (more than 40) calorie distance menus

Fig. 2. Calorie Estimation.

temptational utility difference in case they choose the low-calorie product. In case of an overestimation of the distance, subjects become more vulnerable to choosing the high-calorie food items compared to the case with no bias in the calorie estimates (i.e., agents with the accurate calorie information). For the underestimated calorie distance, the logic works in the opposite direction. If an individual underestimates the calorie distance, then he thinks that the temptational utility sacrificed when choosing the low-calorie food is low. Thus, downward biases in the calorie estimates increase the probability of choosing low-calorie food items. When an individual precisely estimates the calorie distance, he has the same probability of choosing the low-calorie food product compared to an agent who has accurate calorie information. In our model, we show that the overestimated (underestimated) distance burdens the agent with greater (lower) self-control costs compared to the no-bias case, and eventually leads to more (less) frequent self-control failures.

To test our hypothesis, we calculate the difference in estimated and true calorie distances, and we use choices in the Accurate Information as our baseline.[20] We label the choices in the Accurate information condition as "Baseline." Overestimated and underestimated calorie distances are labeled as "Positive" and "Negative, " respectively. Finally, the calorie distance estimates without an error are labeled as "Neutral."

Figure 2 panel (a) shows the distribution of biases in estimations of calorie distances and the number of choices in each category. We observe that the number of Neutral choices is very small. We also observe a small number of outliers both in Negative and Positive observations. In Fig. 2, panel (b) we focus on the observations where the absolute magnitude of the biases is equal or less than 100 calories. It should be noted that this kind of observations constitute around 94% of the data.

Figure 2 panel (b) shows that the average size of the misestimations is around −50 (50) calories for Negative (Positive) observations. When we analyze the percentage of the low-calorie choices across Baseline, Negative, Neutral, and Positive

[20] The magnitude of the bias or misestimation is calculated as: Estimated Belief Calorie Distance − True Calorie Distance.

Table 5
Low-calorie choice tendency and the estimated calorie distance.

	(1)	(2)	(3)	(4)
(Intercept)	0.00***	0.00***	0.00***	0.00***
	(0.00)	(0.00)	(0.00)	(0.00)
Negative	−0.02	−0.03	−0.03	0.02
	(0.04)	(0.05)	(0.05)	(0.06)
Neutral	−0.00	−0.02	−0.02	0.02
	(0.06)	(0.06)	(0.06)	(0.08)
Positive	−0.04	−0.04	−0.04	0.04
	(0.05)	(0.05)	(0.05)	(0.07)
Male		−0.10**	−0.10**	−0.09**
		(0.04)	(0.04)	(0.04)
BMI		0.00	0.00	0.00
		(0.01)	(0.01)	(0.01)
High Income dummy (>60,000 USD)		−0.04	−0.04	−0.04
		(0.04)	(0.04)	(0.04)
More Tempted			−0.01	0.05
			(0.04)	(0.06)
Negative*More Tempted				−0.10
				(0.08)
Neutral*More Tempted				−0.09
				(0.12)
Positive*More Tempted				−0.14*
				(0.09)
AIC	7865.50	7260.08	7261.50	7245.11
BIC	7892.13	7306.17	7314.18	7317.55
Log Likelihood	−3928.75	−3623.04	−3622.75	−3611.56
Deviance	7857.50	7246.08	7245.50	7223.11
Num. obs.	5750	5350	5350	5350

Note: This table displays the analysis of the relationship between the categories of misestimation in calorie distances and low-calorie choices. The dependent variable is a binary measure, and it is "1" when the subject chooses the low-calorie alternative in the binary menu. Neutral dummy means subjects precisely estimated the calories distance. Positive (Negative) dummy means subjects overestimated(underestimated) the calorie distance. The effect of Neutral, Positive and Negative dummies are estimated relative to Baseline dummy. All choices in the Accurate Information condition are represented with Baseline dummy in the regressions.

choices in Fig. 2 panel (c), we do not detect any statistically significant difference. Comparing Neutral and Baseline observations is inconclusive because of the low sample size in Neutral observations. However, both Negative and Positive choices have a sufficient number of observations, but still, we do not detect a significant difference between them and the Baseline choices. Based on Fig. 2 panel (c) we cannot confirm *Hypothesis 4*.

Table 5 shows regression analyses with categories that describe biases in the calorie distance estimation, where the effect of Negative, Positive, and Neutral dummies are compared to the dummy for Baseline choices. The models considered in Table 5 cannot confirm *Hypothesis 4*. We observe that there is no difference between Neutral and Baseline choices, which is in line with *Hypothesis 4*, but because of the small sample size of Neutral observations, we cannot rely on this outcome. Similar to Fig. 2 panel (c), we also do not find any differential effect of Positive and Negative choices contrary to the predictions of *Hypothesis 4*. We find that only in the More Tempted state, the effect of overestimation in the calorie distance has the hypothesized effect. This means, when subjects started the experiment without drinking the protein shake, they were more vulnerable to choose high-calorie snacks if they overestimated the calorie distance. Notice that the accuracy of estimation is endogenous and might be related to individual characteristics. However, being in the More Tempted state is exogenous and allows us to reveal a causal relationship. This result suggests that More Tempted subjects were less likely to choose the low-calorie snacks when they overestimated the calorie distance compared to subjects in the Less Tempted state. The separate effect of the More Tempted state is null, and it is in line with our results from the previous sections. Accordingly, we can conclude that temptation mainly affects choice outcomes through individual beliefs about the relative calorie distance. In our model, in the More Tempted state, an agent experiences a greater self-control cost because temptation increases the magnitude of the temptation utility distance. Observing a significant negative impact of Positive choices compared to Baseline choices in the More Tempted state aligns with our theoretical model.

5.6. The impact of the bias in calorie estimates of individual products on food choices

In our theoretical model, we only focused on the calorie distance; that is why *Hypothesis 4* exclusively focuses on misestimations in the calorie distance and their effects on low-calorie choices. However, an individual can overestimate the distance by overestimating the number of calories in high-calorie foods and/or by underestimating the number of calories in the low-calorie foods. The individual can also underestimate the calorie distance by underestimating the number of calories in the high-calorie food and/or by overestimating the calorie content of the low-calorie foods. Since subjects estimated the calorie distance by separately estimating the calorie content of the products, we have an opportunity to scrutinize the effect of misestimations of the number of calories for each product on low-calorie choices.

Figure 2 panel (d) portrays the relationship between the true calorie difference and the magnitude of misestimations in product calories. The misestimation/bias variable is calculated as the difference between the estimated calorie content and the actual number of calories in the snack. We can observe that an increase in the calorie distance generates more errors in calorie estimations. Another interesting result is that when the distance becomes greater subjects overestimate calories in low-calorie alternatives more compared to high-calorie snacks. A part of this error can be related to the lack of proper knowledge about the nutritional content of products. However, another part of these systematic "mistakes" can be the product of visceral factors that are abundant in food choice environments. Especially, observing that the magnitude of mistakes is larger for low-calorie snacks compared to high-calorie alternatives raises the suspicion that perhaps subjects were trying to justify the consumption of high-calorie snacks by (deliberately) underestimating their calories. Indeed, the post-study survey reveals that on average subjects feel more temptation toward high-calorie snacks, which in turn can explain their more pronounced biased behavior in estimating the calories of low-calorie products.

Figure 2 panels (e) and (f) support our observations from panel (c). In the low-calorie distance menus, subjects demonstrate almost the same amount of misestimation in calories. However, as we move to high-calorie distance menus, we observe that subjects overestimate calories in low-calorie products more compared to their high-calorie alternatives.

The next logical question is "Does the bias in individual calorie estimates affect choice outcomes?" Appendix D presents several analyses to disentangle the effect of biases in the calorie estimates of products on low-calories choices. The results show that an increase in the true calorie distance increases (decreases) the magnitude of the bias in estimated calories of low-calorie (high-calorie) products. This suggests that, as the temptational trade-off between choice alternatives increases, subjects tend to show more biases regarding the calorie content of low-calorie snacks compared to high-calorie alternatives. Our follow-up analyses also show that only the bias in calorie estimates of low-calorie products has an impact on decision outcomes. Specifically, a 100-calorie upward misestimation of the number of calories in low-calorie snacks reduces the probability of choosing the low-calorie alternative by around 7 p.p.

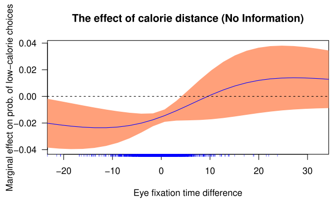
5.7. The impact of visual attention on food choices

We employed eye-trackers in both experiments. The eye-tracking data from the lab experiment is conceptually limited because of the properties of the design (we elaborate about this in Appendix B and E). We present evidence based on this data in Appendix E and show that as subjects fixate more on low-calorie choices, they become more likely to choose the low-calorie alternatives. However, because of the mentioned design properties, our results are suggestive in the lab experiment.

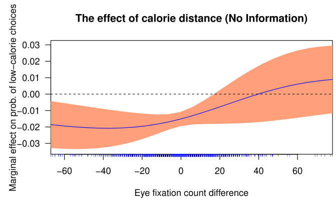
The eye-tracking data from the restaurant experiment is conceptually sound. Here we present our analyses and findings from the second experiment. Before starting our discussion, we have to acknowledge that the eye-tracking data is endogenous. The fixation time each subject spends on product descriptions, calorie information, and product pictures depends on personal characteristics. However, we have a number of treatment variables in our experiment, and our focus is on the moderation effect of visual attention on the probability of choosing low-calorie meals in the restaurant experiment. We focus on eye-fixation time and fixation counts in our discussion.

Figure 3 portrays the moderation effect of visual attention for the calorie distance. Eye fixation time and fixation counts measure the time subjects spent reading the description of meals in binary menus. In all plots, the X-axis shows the difference between the fixation time and fixation counts on the low-calorie and high-calorie alternatives. Positive (negative) values on the X-axis indicate that subjects spent more fixation time and fixation counts on the low-calorie (high-calorie) meals. Figure 3 panels (a) and (b) show that in the No Information condition, the negative effect of the calorie distance is prevalent if subjects spend more fixation time and counts on the high-calorie product. When the time subjects fixate on alternatives is balanced across low-calorie, and high-calorie alternatives in the No Information condition, a 100-calorie increase in the distance reduces the probability of choosing the low-calorie alternatives by 2 p.p. However, more fixation time and fixation counts on the low-calorie alternative neutralize the effect of the calorie distance. When subjects spent more than 5 s of fixation time (or more than 20 fixation counts) on the low-calorie alternative, we do not observe the negative effect of the calorie difference. Since subjects were not provided with the calorie information in the No Information condition, they could infer the calorie distance only by reading the ingredients of the meals. Therefore, it seems more attention to the product descriptions of the low-calorie alternatives helps to reduce the severity of the calorie distance/self-control costs. However, in the Accurate Information condition, if subjects over-fixate on any alternative, the effect of calorie distance vanishes (See Fig. 3 panels (c) and (d)). The calorie distance reduces the probability of low-calorie choices only when subjects spend a similar amount of fixation time and fixation counts on alternatives.

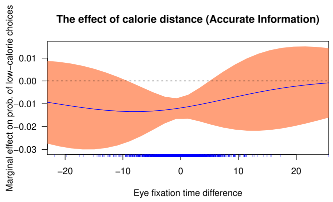
Contrary to the No Information condition, subjects were provided with the calorie information in the Accurate Calorie Information condition. Therefore, we have an opportunity to analyze a potential moderation effect of fixation time and fixation counts on the calorie information part of the screen for the calorie distance. This measure enables the identification of the role of attention to numeric calorie information in altering the effect of self-control cost/calorie distance. The novelty of this analysis is that previous studies mainly focused on the intent-to-treat effects when they disclosed the numeric calorie information to subjects in calorie information conditions. Indeed, there is evidence that relative visual salience dif-



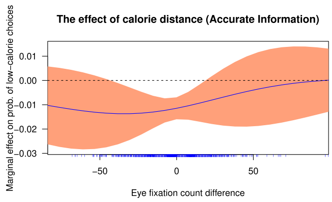
(a) Eye fixation time (in seconds) difference between low and high food products. If positive (negative) a subject spent more time fixating on the description of low-calorie (high-calorie) alternative.



(b) Eye fixation count difference between low and high food products. If positive (negative) a subject had more fixation count on the description of low-calorie (high-calorie) alternative.

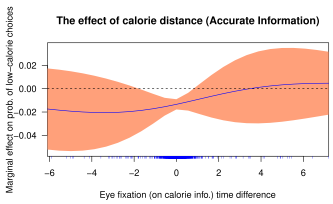


(c) Eye fixation time (in seconds) difference between low and high food products. If positive (negative) a subject spent more time fixating on the description of low-calorie (high-calorie) alternative.

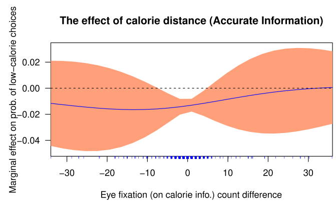


(d) Eye fixation count difference between low and high food products. If positive (negative) a subject had more fixation count on the description of low-calorie (high-calorie) alternative.

Fig. 3. Moderation Effect of Attention to Food Descriptions.



(a) Eye fixation time (in seconds) difference between low and high food products. If positive (negative) a subject spent more time fixating on the calorie information of low-calorie (high-calorie) alternative.



(b) Eye fixation count difference between low and high food products. If positive (negative) a subject had more fixation counts on the calorie information of low-calorie (high-calorie) alternative.

Fig. 4. Moderation Effect of Attention to Calorie Information.

ferences can significantly change decision outcomes in food choices (Mormann et al., 2012). This analysis helps us to have a continuous measure of the information treatment and understand the differential impact of visual salience on food choices.

Figure 4 panels (a) and (b) show that when subjects spend a similar amount of fixation time and fixation counts on the calorie information of both alternatives, the effect of calorie distance is significant. However, if they fixate more on any alternative's calorie information, the effect of the calorie distance vanishes. This result suggests that equal salience of the calorie information of food alternatives does not alter the effect of the menu-dependent self-control cost. Over-attention to any calorie information neutralizes the effect of the calorie distance or the menu-dependent self-control cost. This is important evidence to show that when a decision-maker experiences a trade-off and compares the calorie content of food products by spending the same fixation time on both alternatives, he is vulnerable to the menu-dependent self-control cost. In the case of disproportional attention to any product information, the decision-maker does not face the trade-off, and the effect of the menu-dependent self-control cost vanishes.

Figure 5 displays the moderation effect of the visual attention to product descriptions for the Accurate Information condition. Unlike Fig. 4, the analysis in Fig. 5 intends to show the effect of intent-to-treat (dummy for the Accurate Information condition) and how attention to product descriptions moderates its effects. The Y-axes in both plots show the difference

(a) Eye fixation time (in seconds) difference between low and high food products. If positive (negative) a subject spent more time fixating on the description of low-calorie (high-calorie) alternative.

(b) Eye fixation count difference between low and high food products. If positive (negative) a subject had more fixation count on the description of low-calorie (high-calorie) alternative.

Fig. 5. Compared Moderation Effect of Attention to Food Descriptions .

between the Accurate Information and No Information conditions in terms of low-calorie choices. Figure 5 panels (a) and (b) portray that if we compare observations where subjects spend the same amount of fixation time and fixation counts on product descriptions in both experimental conditions, on average, we see around 10 p.p. more low-calorie choices in the Accurate Information condition. However, we do not see the effect of the Calorie Information condition for observations where subjects exhibit unbalanced fixation time and fixation counts on one of the alternatives. The analysis depicted in Fig. 5 confirms our results from Fig. 4. As in Fig. 4, the effect of the information treatment is prevalent when decision-makers make trade-offs by focusing on alternatives and spend similar fixation times and fixation counts on meal descriptions. The effect of the information condition reduces, when they over-fixate on any alternative.

5.8. Product types and food choices

Appendix F presents several results about the impact of the product types on biases in calorie estimates in the lab experiment. We show that when the calorie trade-off is across the *sugar* dimension, subjects tend to overestimate the number of calories in low-calorie products compared to high-calorie products. When the calorie trade-off is across the *fat* dimension or when the source of the calorie reduction is *undisclosed*, subjects demonstrate the same level of biases for low and high-calorie snacks in their calorie estimations. We also show that when the estimated calorie distance between products increases by 100 calories, the probability of choosing low calorie-snacks decreases around 9 p.p. in the *sugar* dimension, but we do not detect an effect for the other dimensions. Overall, our analyses show that biases in calorie estimates are also strongly related to product types.

5.9. Calorie budgeting and food choices

Appendix G presents our analysis on whether subjects are calorie budgeting when they are provided with the accurate calorie information in the restaurant experiment. We show that when subjects have the accurate information and they know which meal they are going to eat, they consume more beverage calories compared to the No Information condition. In the same situation, they tend to consume fewer dessert calories compared to the No Information condition. This finding suggests that the calorie budgeting phenomenon is prevalent only in dessert choices and not in beverage choices.

6. Discussion and conclusions

Menu-dependent preferences have gained a great deal of attention (Gul and Pesendorfer, 2001; Noor and Takeoka, 2015; Olszewski, 2011; Frick, 2016; Gómez-Miñambres and Schniter, 2014). The primary promise of this emerging literature is that choice outcomes depend greatly on the salience of "competing" cues in the choice environment (Bordalo et al., 2013; Gabaix et al., 2006; Mormann et al., 2012). The seminal paper of Gul and Pesendorfer (2001) was the very first attempt to model menu-dependent preferences within the axiomatic choice framework. Noor and Takeoka (2015) made one of the first attempts to pin down the self-control costs of different menus. However, the endogenous nature of derived temptational utilities and associated self-control costs impedes documenting the theorized causal relationships between self-control issues and food decisions in secondary data sources.

Although laboratory studies are prone to experimenter demand effect, they also provide controlled environments to identify potential behavioral mechanisms stimulating low-calorie choices. This venue of research can eventually offer promising testable behavioral hypothesis for secondary data studies. This study continues this effort, and through lab and restaurant experiments, shows the importance of menu-dependent self-control costs in food choices. We show that the relative calorie distance between food choice alternatives affects temptational utility differences and the calorie distance can serve as a plausible proxy in studying the modeled causal impact of self-control costs on food choices. We exogenously manipulate the calorie difference between food items in binary menus and provide strong evidence that an increase in the relative calorie distance reduces the probability of choosing low-calorie choices both in the lab experiment when the trade-off is between snacks, and in the restaurant experiment when food choices are made in a real restaurant environment with full meals.

This paper also ties menu-dependent preferences and subsequent menu-dependent self-control costs to the effectiveness of calorie information when provided with food choices. As noted, both secondary data and experimental studies report mixed results in this regard. We show that while providing calorie information increases the probability of choosing low-calorie choices, this effect is counterbalanced by menu-dependent self-control costs. Thus, the projected effect of the calorie labeling laws is discounted by menu specifics. The policy relevance of this result is that calorie labeling laws exclusively focus on the demand and intend to nudge consumers. The supply side, however, is also important. Menus or choice environments can play a crucial role in moderating the expected impact of calorie information. Bringing food retailers on board in terms of nudging consumers to reduce calorie intake might be more effective in improving public health. Future studies should also focus on the reaction of food retailers to calorie labeling laws in order to provide a more detailed picture of the consequences of listing calorie information.

Our study also speaks to an emerging literature on the importance of motivated biases (Coutts, 2019; Bénabou and Tirole, 2016; Mayraz, 2011). We show that individual beliefs about calories are subject to systematic biases, and that these biases depend on menu-dependent self-control costs. The Homegrown Information condition of the lab experiment shows that consumers are more vulnerable to food-related temptation, especially when they do not have accurate calorie information and consequently are forced to rely on their personal beliefs. We find that as the true calorie distance between products increases, subjects overestimate the calorie content of the low-calorie alternative to a greater extent than that of the high-calorie alternative. We also show that only the bias in the estimation of the number of calories in the low-calorie products has a non-zero effect and significantly reduces the probability of choosing the low-calorie alternatives. Additionally, these results are prevalent only when the calorie trade-off is made because of the amount of sugar present. Our findings could stem from the understanding that the Homegrown knowledge of calories also relates to individual characteristics, which in turn may also relate to individual preferences for healthy food. In fact, Wisdom et al. (2010) find a strong relationship between errors in the perceived calorie content of food products and demographic variables. For instance, females are less likely to misestimate the number of calories in meals compared to males. Temptation may also impair the cognitive function responsible for retrieving existing knowledge from the brain. Previous studies already establish a convincing link between cognitive load and temptation (Shiv and Fedorikhin, 1999; Levine and Fudenberg, 2006). Our findings suggest that consumers may be less precise in estimating calories when food cues induce temptation. Overall, our results demonstrate the importance of biases in calorie estimates in food choices and their connection to menu-dependent self-control costs.

Finally, eye-tracking technology enables us to go beyond an intent-to-treat type of analysis and allows us to explore the moderation effect of the continuous measure of visual attention on food choices. We show that low-calorie choices are positively correlated with the attention given to images of low-calorie alternatives in the lab experiment. Menu-dependent self-control costs are also sensitive to the salience of the food descriptions in the restaurant experiment. We also show that the positive effect of the calorie information on the probability of choosing the low-calorie alternative is significant when subjects pay similar amounts of visual attention to food alternatives. Thus, we show that the bias in visual attention can significantly alter the effect of information-provision on food choices.

Declaration of Competing Interest

Samir Huseynov declares that received NSF DRMS-1658816 support to conduct this project. Other than this, Samir Huseynov declares that he has no relevant or material financial interests that relate to the research described in this paper.

Marco A. Palma declares that received NSF DRMS-1658816 support to conduct this project. Other than this, Marco A. Palma declares that he has no relevant or material financial interests that relate to the research described in this paper.

Ghufran Ahmad declares that he has no relevant or material financial interests that relate to the research described in this paper.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at 10.1016/j.jebo.2021.05.037.

References

Allcott, H., Diamond, R., Dubé, J.-P., Handbury, J., Rahkovsky, I., Schnell, M., 2019. Food deserts and the causes of nutritional inequality. Q. J. Econ. 134 (4), 1793–1844.

Alonso-Alonso, M., Woods, S.C., Pelchat, M., Grigson, P.S., Stice, E., Farooqi, S., Khoo, C.S., Mattes, R.D., Beauchamp, G.K., 2015. Food reward system: current perspectives and future research needs. Nutr. Rev. 73 (5), 296–307.

Alós-Ferrer, C., Hügelschäfer, S., Li, J., 2015. Self-control depletion and decision making.. J. Neurosci. Psychol. Econ. 8 (4), 203.

Angeletos, G.-M., Laibson, D., Repetto, A., Tobacman, J., Weinberg, S., 2001. The hyperbolic consumption model: calibration, simulation, and empirical evaluation. J. Econ. Perspect. 15 (3), 47–68.

Beaulac, J., Kristjansson, E., Cummins, S., 2009. Peer reviewed: a systematic review of food deserts, 1966–2007. Prev. Chronic Dis. 6 (3).

Bénabou, R., Tirole, J., 2016. Mindful economics: the production, consumption, and value of beliefs. J. Econ. Perspect. 30 (3), 141–164.

Berning, J.P., Chouinard, H.H., McCluskey, J.J., 2011. Do positive nutrition shelf labels affect consumer behavior? Findings from a field experiment with scanner data. Am. J. Agric. Econ. 93 (2), 364–369.

Berns, G.S., Laibson, D., Loewenstein, G., 2007. Intertemporal choice–toward an integrative framework. Trends Cogn. Sci. 11 (11), 482–488.
Bleich, S.N., Economos, C.D., Spiker, M.L., Vercammen, K.A., VanEpps, E.M., Block, J.P., Elbel, B., Story, M., Roberto, C.A., 2017. A systematic review of calorie labeling and modified calorie labeling interventions: impact on consumer and restaurant behavior. Obesity 25 (12), 2018–2044.
Bollinger, B., Leslie, P., Sorensen, A., 2011. Calorie posting in chain restaurants. Am. Econ. J. Econ. Policy 3 (1), 91–128.
Bordalo, P., Gennaioli, N., Shleifer, A., 2013. Salience and consumer choice. J. Polit. Economy 121 (5), 803–843.
Brown, A.L., Chua, Z.E., Camerer, C.F., 2009. Learning and visceral temptation in dynamic saving experiments. Q. J. Econ. 124 (1), 197–231.
Bushong, B., King, L.M., Camerer, C.F., Rangel, A., 2010. Pavlovian processes in consumer choice: the physical presence of a good increases willingness-to-pay. Am. Econ. Rev. 100 (4), 1556–1571.
Camerer, C.F., 2013. Goals, methods, and progress in neuroeconomics. Annu. Rev. Econ. 5 (1), 425–455.
Cawley, J., Susskind, A., Willage, B., 2018. The Impact of Information Disclosure on Consumer Behavior: Evidence from a Randomized Field Experiment of Calorie Labels on Restaurant Menus. Technical Report. National Bureau of Economic Research.
Cecchini, M., Sassi, F., Lauer, J.A., Lee, Y.Y., Guajardo-Barron, V., Chisholm, D., 2010. Tackling of unhealthy diets, physical inactivity, and obesity: health effects and cost-effectiveness. Lancet 376 (9754), 1775–1784.
Choplin, J.M., Wedell, D.H., 2014. How many calories were in those hamburgers again? Distribution density biases recall of attribute values. Judgm. Decis. Mak. 9 (3), 243.
Clithero, J.A., 2018. Improving out-of-sample predictions using response times and a model of the decision process. J. Econ. Behav. Organ. 148, 344–375.
Cooksey-Stowers, K., Schwartz, M.B., Brownell, K.D., 2017. Food swamps predict obesity rates better than food deserts in the united states. Int. J. Environ. Res. Public Health 14 (11), 1366.
Coutts, A., 2019. Testing models of belief bias: an experiment. Games Econ. Behav. 113, 549–565.
Dallas, S.K., Liu, P.J., Ubel, P.A., 2019. Don't count calorie labeling out: calorie counts on the left side of menu items lead to lower calorie food choices. J. Consum. Psychol. 29 (1), 60–69.
Deierlein, A.L., Peat, K., Claudio, L., 2015. Comparison of the nutrient content of childrens menu items at us restaurant chains, 2010–2014. Nutr. J. 14 (1), 80.
Dekel, E., Lipman, B.L., Rustichini, A., 2001. Representing preferences with a unique subjective state space. Econometrica 69 (4), 891–934.
Dekel, E., Lipman, B.L., Rustichini, A., 2009. Temptation-driven preferences. Rev. Econ. Stud. 76 (3), 937–971.
Drichoutis, A.C., Lazaridis, P., Nayga, R.M., 2006. Consumers' use of nutritional labels: a review of research studies and issues. Acad. Mark. Sci. Rev. 9 (9), 1–22.
Dumanovsky, T., Huang, C.Y., Nonas, C.A., Matte, T.D., Bassett, M.T., Silver, L.D., 2011. Changes in energy content of lunchtime purchases from fast food restaurants after introduction of calorie labelling: cross sectional customer surveys. BMJ 343, d4464.
Elbel, B., Kersh, R., Brescoll, V.L., Dixon, L.B., 2009. Calorie labeling and food choices: a first look at the effects on low-income people in new york city. Health Aff. 28 (6), w1110–w1121.
Ellison, B., Lusk, J.L., Davis, D., 2014. The effect of calorie labels on caloric intake and restaurant revenue: evidence from two full-service restaurants. J. Agric. Appl. Econ. 46 (2), 173–191.
Ellison, B., Lusk, J.L., Davis, D., 2014. The impact of restaurant calorie labels on food choice: results from a field experiment. Econ. Inq. 52 (2), 666–681.
Ericson, K.M., Laibson, D., 2018. Intertemporal Choice. Technical Report. National Bureau of Economic Research.
Fernandes, A.C., Oliveira, R.C., Proença, R.P., Curioni, C.C., Rodrigues, V.M., Fiates, G.M., 2016. Influence of menu labeling on food choices in real-life settings: a systematic review. Nutr. Rev. 74 (8), 534–548.
Finkelstein, E.A., Strombotne, K.L., Chan, N.L., Krieger, J., 2011. Mandatory menu labeling in one fast-food chain in King County, Washington. Am. J. Prev. Med. 40 (2), 122–127.
Frick, M., 2016. Monotone threshold representations. Theor. Econ. 11 (3), 757–772.
Fudenberg, D., Levine, D.K., 2006. A dual-self model of impulse control. Am. Econ. Rev. 96 (5), 1449–1476.
Fudenberg, D., Levine, D.K., 2012. Timing and self-control. Econometrica 80 (1), 1–42.
Gabaix, X., Laibson, D., Moloche, G., Weinberg, S., 2006. Costly information acquisition: experimental analysis of a boundedly rational model. Am. Econ. Rev. 1043–1068.
Ghosh-Dastidar, B., Cohen, D., Hunter, G., Zenk, S.N., Huang, C., Beckman, R., Dubowitz, T., 2014. Distance to store, food prices, and obesity in urban food deserts. Am. J. Prev. Med. 47 (5), 587–595.
Gómez-Miñambres, J., Schniter, E., 2014. Menu-dependent emotions and self-control. Available at SSRN 2152036.
Gul, F., Pesendorfer, W., 2001. Temptation and self-control. Econometrica 69 (6), 1403–1435.
Gul, F., Pesendorfer, W., 2004. Self-control, revealed preference and consumption choice. Rev. Econ. Dyn. 7 (2), 243–264.
Hagger, M.S., Chatzisarantis, N.L., Alberts, H., Anggono, C.O., Batailler, C., Birt, A.R., Brand, R., Brandt, M.J., Brewer, G., Bruyneel, S., et al., 2016. A multilab preregistered replication of the ego-depletion effect. Perspect. Psychol. Sci. 11 (4), 546–573.
Huseynov, S., Kassas, B., Segovia, M.S., Palma, M.A., 2019. Incorporating biometric data in models of consumer choice. Appl. Econ. 51 (14), 1514–1531.
Kőszegi, B., Szeidl, A., 2012. A model of focusing in economic choice. Q. J. Econ. 128 (1), 53–104.
Krajbich, I., 2018. Accounting for attention in sequential sampling models of decision making. Curr. Opin. Psychol..
Kuehn, B., 2018. Obesity rates increasing. JAMA 320 (16). 1632–1632
Laibson, D., 1997. Golden eggs and hyperbolic discounting. Q. J. Econ. 112 (2), 443–478.
Levine, D., Fudenberg, D., 2006. A dual-self model of impulse control. Am. Econ. Rev. 96 (5), 1449–1476.
Loewenstein, G., 2000. Emotions in economic theory and economic behavior. Am. Econ. Rev. 90 (2), 426–432.
Lurquin, J.H., Miyake, A., 2017. Challenges to ego-depletion research go beyond the replication crisis: a need for tackling the conceptual crisis. Front. Psychol. 8, 568.
de Macedo, I.C., de Freitas, J.S., da Silva Torres, I.L., 2016. The influence of palatable diets in reward system activation: a mini review. Adv. Pharmacol. Sci. 2016.
Masatlioglu, Y., Nakajima, D., Ozbay, E.Y., 2016. Revealed attention. In: Behavioral Economics of Preferences, Choices, and Happiness. Springer, pp. 495–522.
Mayraz, G., 2011. Wishful thinking. Available at SSRN 1955644.
Morland, K., Roux, A.V.D., Wing, S., 2006. Supermarkets, other food stores, and obesity: the atherosclerosis risk in communities study. Am. J. Prev. Med. 30 (4), 333–339.
Mormann, M.M., Navalpakkam, V., Koch, C., Rangel, A., 2012. Relative visual saliency differences induce sizable bias in consumer choice.
Muraven, M., Baumeister, R.F., 2000. Self-regulation and depletion of limited resources: does self-control resemble a muscle? Psychol. Bull. 126 (2), 247.
Namba, A., Auchincloss, A., Leonberg, B.L., Wootan, M.G., 2013. Peer reviewed: exploratory analysis of fast-food chain restaurant menus before and after implementation of local calorie-labeling policies, 2005–2011. Prev. Chronic Dis. 10.
Nelson, P., 1970. Information and consumer behavior. J. Polit. Economy 78 (2), 311–329.
Nelson, P., 1974. Advertising as information. J. Polit. Economy 82 (4), 729–754.
Noor, J., 2007. Commitment and self-control. J Econ Theory 135 (1), 1–34.
Noor, J., 2011. Temptation and revealed preference. Econometrica 79 (2), 601–644.
Noor, J., Takeoka, N., 2010. Uphill self-control. Theor. Econ. 5 (2), 127–158.
Noor, J., Takeoka, N., 2015. Menu-dependent self-control. J. Math. Econ. 61, 1–20.
O'Donoghue, T., Rabin, M., 1999. Doing it now or later. Am. Econ. Rev. 89 (1), 103–124.
Olszewski, W., 2011. A model of consumption-dependent temptation. Theory Decis. 70 (1), 83–93.
Palma, M.A., Segovia, M.S., Kassas, B., Ribera, L.A., Hall, C.R., 2018. Self-control: knowledge or perishable resource? J. Econ. Behav. Organ. 145, 80–94.
Pang, J., Hammond, D., 2013. Efficacy and consumer preferences for different approaches to calorie labeling on menus. J. Nutr. Educ. Behav. 45 (6), 669–675.

Shiv, B., Fedorikhin, A., 1999. Heart and mind in conflict: the interplay of affect and cognition in consumer decision making. J. Consum. Res. 26 (3), 278–292.
Stigler, G.J., 1961. The economics of information. J. Polit. Economy 69 (3), 213–225.
Strotz, R.H., 1955. Myopia and inconsistency in dynamic utility maximization. Rev. Econ. Stud. 23 (3), 165–180.
Tangari, A.H., Bui, M., Haws, K.L., Liu, P.J., 2019. That is not so bad, i will eat more! backfire effects of calories-per-serving information on snack consumption. J. Mark. 83 (1), 133–150.
Toussaert, S., 2018. Eliciting temptation and self-control through menu choices: a lab experiment. Econometrica 86 (3), 859–889.
USDA, 2015. 2015–2020 Dietary Guidelines for Americans. Washington (DC): USDA.
Vadillo, M.A., Gold, N., Osman, M., 2016. The bitter truth about sugar and willpower: the limited evidential value of the glucose model of ego depletion. Psychol. Sci. 27 (9), 1207–1214.
Vul, E., Goodman, N., Griffiths, T.L., Tenenbaum, J.B., 2014. One and done? optimal decisions from very few samples. Cogn. Sci. 38 (4), 599–637.
Wardle, J., Huon, G., 2000. An experimental investigation of the influence of health information on children's taste preferences. Health Educ. Res. 15 (1), 39–44.
Wisdom, J., Downs, J.S., Loewenstein, G., 2010. Promoting healthy choices: information versus convenience. Am. Econ. J. 2 (2), 164–178.