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RESEARCH ARTICLE

Online Randomized Controlled Trials of Restaurant Sodium Warning Labels

Aviva A. Musicus, BA,[1] Alyssa J. Moran, ScD, RD,[2] Hannah G. Lawman, PhD,[3] Christina A. Roberto, PhD[4]

Introduction: Policymakers are interested in requiring chain restaurants to display sodium warning labels on menus to reduce sodium consumption. This study examined the influence of label design on consumers' hypothetical choices, meal perceptions, and knowledge.

Study design: Four sequential, randomized, controlled online experiments were conducted.

Setting/participants: Across all 4 experiments, 10,412 sociodemographically diverse participants were recruited online through Survey Sampling International and Amazon Mechanical Turk.

Intervention: Participants were randomized to view restaurant menus with either no sodium label (control) or 1 of 13 sodium warning labels that varied the text (e.g., "sodium warning" versus "high sodium"), icons (e.g., stop sign), and colors (red/black) used. Participants placed a hypothetical meal order and rated restaurant meal perceptions. Data were collected and analyzed in 2016−2019.

Main outcome measures: The primary outcome was sodium content of hypothetical restaurant choices. Secondary outcomes included restaurant meal perceptions and sodium knowledge.

Results: In Experiments 1−3, all warning labels reduced average sodium ordered across both restaurants (by 19−81 mg) versus controls, with some of the largest reductions from traffic light and stop sign labels, but results were not statistically significant. In a larger, preregistered replication (Experiment 4) testing traffic light and red stop sign labels versus control, traffic light and red stop sign labels significantly reduced average sodium ordered across both restaurants (−68 mg, p=0.002 and −46 mg, p=0.049, respectively). Warnings also significantly increased participants' knowledge of sodium content and perceived health risks associated with high-sodium meals compared with no label.

Conclusions: Traffic light and red stop sign warning labels significantly reduced sodium ordered compared with a control. Warning labels also increased knowledge about high sodium content in restaurant meals. Designs with warning text are likely to improve consumer understanding.
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INTRODUCTION

Almost half of Americans have high blood pressure,[1] which is a major risk factor for heart disease and stroke.[2,3] High sodium intake contributes to high blood pressure, and 89% of American adults consume more than the sodium upper limit (2,300 mg) recommended by the *2015−2020 Dietary Guidelines for Americans*.[4] One quarter of dietary sodium comes from restaurant foods,[5] compared with only 11% from adding salt at home during cooking or at the table.[6] Although there are many factors that contribute to

From the [1]Department of Nutrition, Harvard T.H. Chan School of Public Health, Boston, Massachusetts; [2]Department of Health Policy and Management, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland; [3]Division of Chronic Disease Prevention, Philadelphia Department of Public Health, Philadelphia, Pennsylvania; and [4]Department of Medical Ethics and Health Policy, Perelman School of Medicine at the University of Pennsylvania, Philadelphia, Pennsylvania

Address correspondence to: Aviva A. Musicus, BA, Department of Nutrition, Harvard T.H. Chan School of Public Health, 655 Huntington Avenue, Building II, Room 320, Boston MA 02115.
E-mail: aam231@mail.harvard.edu.
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overconsumption of sodium-rich foods, one barrier to lowering sodium intake is that consumers are largely unaware of the sodium content of restaurant foods, underestimating it by an average of 1,000 mg per meal.[7,8]

In 2016, New York City (NYC) became the first U.S. city to require chain restaurants with 15 or more locations nationwide to post sodium warning labels next to menu items and combination meals containing more sodium than the recommended daily limit (2,300 mg).[9] Philadelphia has since passed a similar law.[10] This policy aims to inform consumers about items with excessive sodium content at the point of sale and may prompt restaurants to reduce sodium content to avoid labels. Warning labels on tobacco products and sugar-sweetened beverages have been shown to increase risk perceptions, improve knowledge, and affect behavior.[11−15] In restaurants, purely informational labels (e.g., milligrams of sodium, number of calories) have had mixed behavioral effects, so an explicit warning label that provides information on health consequences and makes that information more salient may be more effective.[8,16−20] No studies, to the authors' knowledge, have evaluated how consumers react to a range of sodium warning labels on restaurant menus or which label designs are likely to be most influential in the restaurant setting. The primary aim of this study was to assess the extent to which sodium warning labels using different words, icons, and colors influence the sodium content of hypothetical restaurant choices (primary outcome), restaurant meal perceptions, and sodium knowledge (secondary outcomes).

METHODS

Study Sample

Four randomized, controlled online experiments were conducted sequentially using similar designs. The first 2 experiments aimed to identify the best-performing warning text, the third tested that text in combination with different icons and colors to determine the most influential overall design, and the fourth was a preregistered, sufficiently powered replication trial to test the 2 best-performing designs against a control. Separate samples of U.S. residents aged ≥18 years were recruited through Amazon Mechanical Turk (MTurk), an online marketplace where people are paid to complete tasks. This platform has been shown to provide reliable responses, especially when a data integrity question is included.[21,22] For Experiment 3, an additional sample of participants with a demographic composition similar to Philadelphia was recruited through Survey Sampling International (SSI), an online panel of U.S. consumers, to inform Philadelphia's warning label bill (Figure 1 and Appendix Figures 1−3, available online).

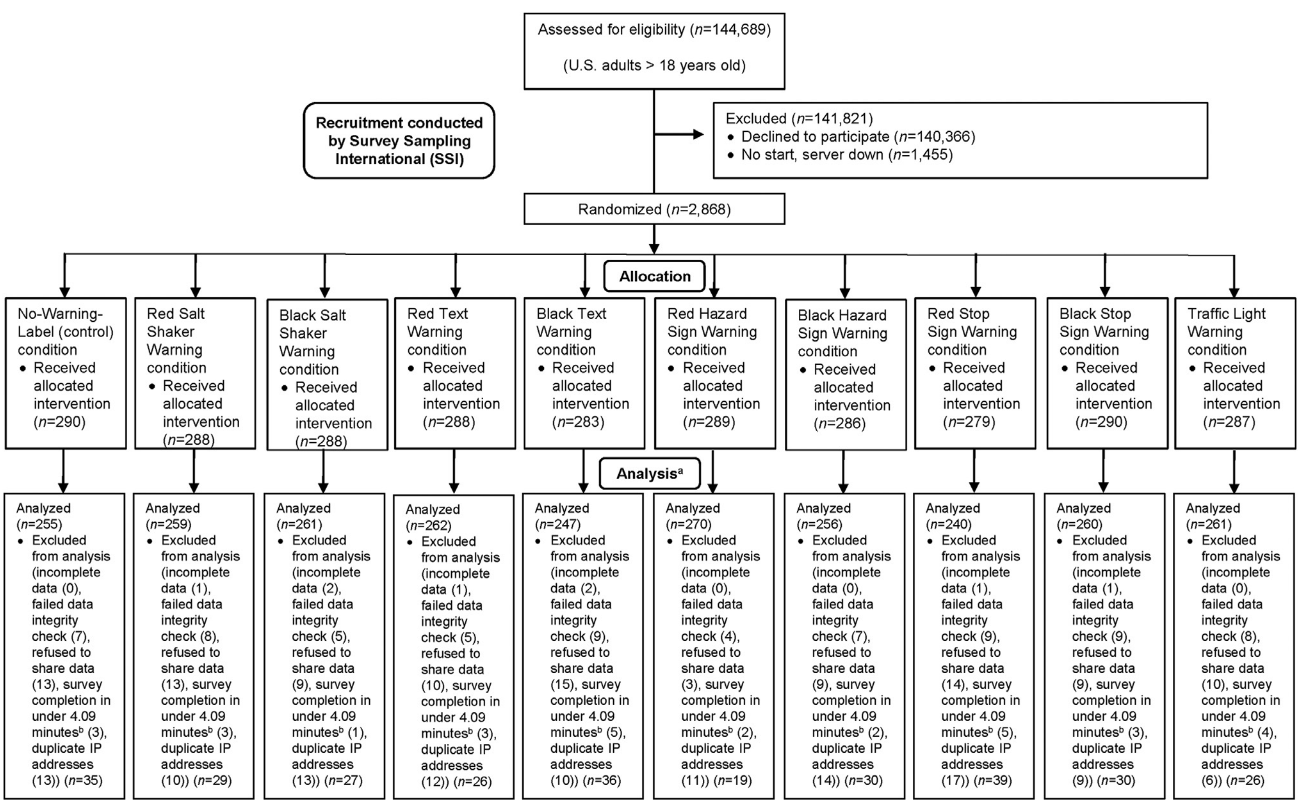

Figure 1. Experiment 3 CONSORT diagram for Survey Sampling International sample.
[a]This sample was combined with the MTurk sample shown in Figure 2 for all Experiment 3 analyses. Some participants met multiple exclusion criteria, so final n excluded does not always equal the sum of each separate exclusion criterion n.
[b]One third of the median completion time, 12.27 minutes.

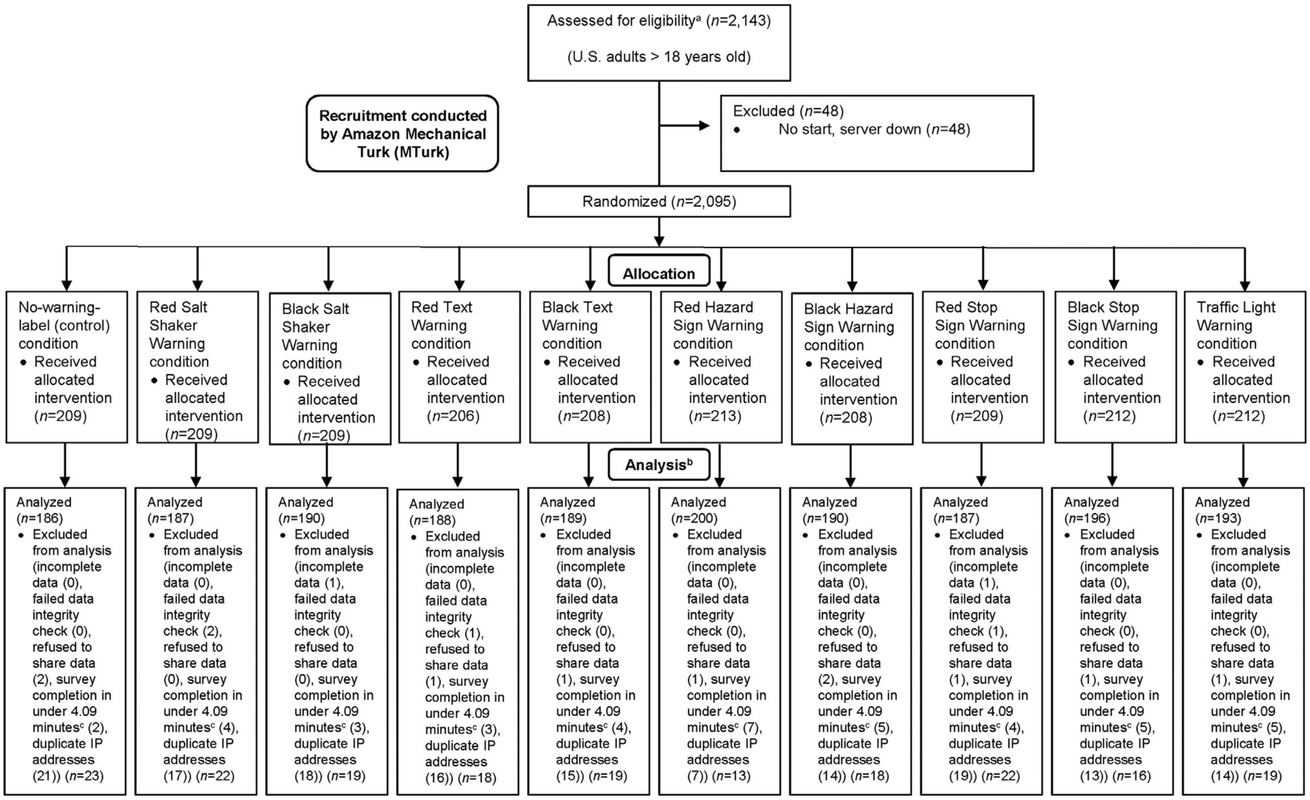

Figure 2. Experiment 3 CONSORT diagram for MTurk sample.
[a]Number approached to take study unknown.
[b]This sample was combined with the Survey Sampling International sample shown in Figure 1 for all Experiment 3 analyses. Some participants met multiple exclusion criteria, so final *n* excluded does not always equal the sum of each separate exclusion criterion *n*.
[c]One third of the median completion time, 12.27 minutes.

Data were collected and analyzed in October 2016–May 2019. The University of Pennsylvania and Harvard T.H. Chan School of Public Health IRBs approved this study.

Measures

Figure 3 summarizes each experiment's aims and hypotheses and displays images of each label condition. In each experiment, participants completed an online survey in which they were randomized through the Qualtrics survey platform using simple randomization to view 2 restaurant menus (Dairy Queen [fast food] and TGI Fridays [full service]) with either calorie labels only next to all menu items (control group) or calorie labels next to all menu items plus 1 of several sodium warning labels next to items exceeding 2,300 mg of sodium. One fast-food and 1 full-service chain restaurant were selected because sodium warnings may, like calorie labels, have larger effects in full-service restaurants compared with fast food because sodium (and calorie) content tends to be higher, and there is more time to view the menu.[18] Both restaurants are subject to the NYC and Philadelphia laws and have multiple menu items with >2,300 mg of sodium. Calorie labels were included in the control condition because U.S. chain restaurants are required to post calories on menus.[23] Restaurant menus included the required daily calorie recommendation statement, and those with sodium warnings also displayed the following text required by NYC law[9]: "Warning: [sodium warning label] indicates that the sodium (salt) content of this item is higher than the total daily recommended limit (2,300 mg). High sodium intake can increase blood pressure and risk of heart disease and stroke." Sodium information was obtained from the restaurants' websites. The Appendix (available online) contains all survey items and images.

After providing informed consent, participants made hypothetical meal choices from 2 restaurant menus and answered survey questions. All outcomes are described as follows:

Participants first rated their hunger levels. They were then shown a fast-food and full-service restaurant menu in random order and asked to order a meal from each as if they were at the restaurant at that moment for dinner. Menus were from restaurant websites and displayed a subset of items. The primary outcome was average sodium (mg) ordered across both menus. Average sodium ordered at each restaurant and the percentage of participants choosing at least 1 high-sodium (>2,300 mg) meal were also examined.

After ordering meals, participants in Experiments 1–3 were shown images of 4 meals (2 from each restaurant) that included meal names, descriptions, and prices. These meals did not appear on the previous menus and were displayed one at a time in random order. Two meals contained >2,300 mg sodium and were labeled with warning labels (except in the control condition). Two

Experiment	Aims	Hypothesis	Label Conditions *All non-control conditions featured warning labels next to any menu item that contained more than 2,300 mg of sodium*	
1	• Determine the extent to which text-based sodium warning labels would reduce the average sodium content of hypothetical restaurant purchases and influence restaurant item perceptions, knowledge, and label use compared to no label. • Determine the extent to which the words "salt", "sodium", or "warning" have differential effects on outcomes.	We hypothesized that: • All warning labels would reduce average sodium content ordered, but the "salt" label would be most influential because people are more familiar with the word "salt" compared to "sodium."	A. No-warning-label control B. High Salt label HIGH SALT C. High Sodium label HIGH SODIUM D. Sodium Warning label SODIUM WARNING	
2	• Determine the extent to which different phrases would influence consumers' hypothetical restaurant orders and health-related perceptions of menu items.	Based on results from experiment 1, we hypothesized that: • "Salt warning" will result in a similar average sodium content ordered compared to "sodium warning", and may increase perceptions of saltiness. However, differences between the two warning labels are unlikely to be practically meaningful.	A. Sodium Warning label SODIUM WARNING B. Salt Warning label SALT WARNING	
3	• Determine the extent to which sodium warning labels would reduce the average sodium content of hypothetical restaurant purchases and influence restaurant item perceptions, knowledge, and label use compared to no label. • Compare the effects of different label designs and colors (red versus black).	Based on the first two experiments, we hypothesized that: • Labels with "sodium warning" text would reduce average sodium content ordered • All labels would increase estimates of sodium content and consumer perceptions of saltiness and decrease likelihood of ordering. • The presence of any sodium warning label would decrease perceptions of healthfulness and increase perceptions of an association with weight gain and high blood pressure.	A. No-warning-label control	
			B. Red Salt Shaker label	C. Black Salt Shaker label (in use in NYC)
			D. Red Hazard Sign label ⚠ SODIUM WARNING	E. Black Hazard Sign label ⚠ SODIUM WARNING
			F. Red Stop Sign label ● SODIUM WARNING	G. Black Stop Sign label ● SODIUM WARNING
			H. Red Text label SODIUM WARNING	I. Black Text label SODIUM WARNING
			J. Traffic Light label *Red: items >2,300 mg sodium* SODIUM WARNING *Yellow: items >1,500 mg and ≤2,300 mg sodium* HIGH SODIUM *Green: items ≤140 mg sodium per 100g (per FDA health claim regulations for "low sodium")* LOW SODIUM	
4	• Use a pre-registered, sufficiently-powered replication trial to determine the extent to which a red stop sign label, traffic light label, and control would influence consumers' hypothetical restaurant orders.	Based on the first three experiments, we hypothesized that: • The traffic light and red stop sign labels would significantly reduce average sodium ordered compared to the control.	A. No-warning-label control B. Red Stop Sign label ● SODIUM WARNING C. Traffic Light label (see 3J above for description) SODIUM WARNING, HIGH SODIUM, LOW SODIUM	

Figure 3. Experiment aims, hypotheses, and label conditions.
FDA, U.S. Food and Drug Administration; NYC, New York City.

meals contained ≤2,300 mg sodium and did not qualify for warning labels. Participants rated their perceptions of the meals' deliciousness, saltiness, healthfulness, and potential contribution to disease risk and indicated how likely they were to purchase each meal on a 5-point Likert scale. Participants also estimated the meals' sodium and calorie contents, on both an ordinal scale from 1 (none) to 4 (a lot) and a continuous scale (open text response restricted to 0–10,000) in milligrams or calories, respectively. Responses were averaged separately for the meals with >2,300 mg and ≤2,300 mg of sodium. In Experiments 1 and 3, participants also completed a comparison task in which they were shown 3 sets of 2 meals side by side and asked to select the meal with more sodium. Two questions showed a meal with ≤2,300 mg sodium (not labeled) compared with a meal with >2,300 mg sodium (labeled). One question showed 2 meals that both had >2,300 mg sodium (both labeled). Question order and meal position (left or right) were randomized. The 2 outcome measures were whether participants correctly answered (1) both questions comparing a labeled with an unlabeled meal and (2) the question comparing 2 labeled meals.

At the end of Experiment 1, participants were shown all 3 sodium warning labels and asked which was most helpful in conveying a meal had an unhealthy amount of a certain ingredient. At the end of Experiments 1 and 3, participants indicated whether they had seen a warning label next to any menu item and whether it influenced what they ordered.

At the end of the survey, participants reported how often they ate at full-service and fast-food restaurants and how much sodium and calories are recommended daily for the average adult. Additional demographics are displayed in Appendix Table 1 (available online).

Statistical Analysis

In each experiment, differences in hunger levels and demographics across conditions were tested using ANOVAs for continuous variables and chi-square tests for categorical variables. Linear and logistic regressions were used to respectively compare continuous and categorical outcomes across conditions. Wilcoxon rank sum tests were used to compare the secondary outcome of participants' median sodium content estimates between conditions, because the data contained extreme outliers and were highly skewed. All analyses used the Holm–Bonferroni procedure to correct for multiple comparisons,[24] and all listed *p*-values are corrected. Uncorrected *p*-values are also reported if they were significant but corrected values were not significant. In Experiment 3, labeling arms were collapsed to compare mean responses by label color (control, red labels, black labels, and traffic light labels) and design (control, salt shaker, sodium warning text alone, hazard sign, stop sign, and traffic light), because no significant differences in outcomes between red and black versions of the same labels were found. Using G*Power software (Version 3.1.9.4) and the average SD across the first 3 experiments, assuming an α of 0.05, a post-hoc power analysis showed Experiments 1, 2, and 3 were powered at 80% to detect respective differences of 131 mg, 115 mg, and 99 mg (4%−6% of the recommended daily limit) in average sodium ordered between any 2 groups. Observed effects were slightly smaller than this, so a sufficiently powered, preregistered, replication trial was conducted (Experiment 4) to test menu choice outcomes for the top-performing labels versus a control (preregistration described in the Appendix, available online).

RESULTS

Experiment 1 tested which of 3 sodium warning label phrasings would be most influential. Participants (N=1,077) were recruited from MTurk and randomized to either a control condition or 1 of 3 text-only warning label conditions: "high salt," "high sodium," or "sodium warning." Participants were excluded before analysis for providing incomplete data, refusing to share data, completing the survey in less than one third of the median completion time, using a duplicate IP address, or failing the data integrity check (n=41) (Appendix Figure 1, available online). The final sample (n=1,036) was balanced on hunger levels and demographic characteristics across conditions (Appendix Table 1, available online).

Detailed Experiment 1 results appear in the Appendix (available online). In summary, the average sodium ordered across both menus did not significantly differ by condition. Stratifying by restaurant, "sodium warning" label participants ordered 151 mg (12%) less sodium than the control group from the fast-food menu (p=0.030) (Table 1). The "high salt" label was significantly more likely to increase consumer perceptions of the health risks of regularly consuming high-sodium meals. Because average sodium ordered was the primary outcome, Experiment 2 tested "salt warning" versus "sodium warning" labels to see which would have a larger influence on behavioral intentions and perceptions.

Experiment 2 tested whether the phrasing "salt warning" versus "sodium warning" would be more likely to influence behavioral intentions and perceptions. Participants (N=687) were recruited and randomized to either a "salt warning" or "sodium warning" label. Twenty-two participants were excluded using Experiment 1 criteria (Appendix Figure 2, available online). The final sample included 665 participants (Appendix Table 1, available online). Although 2 variables, assessed at the end of the survey ("trying to reduce sodium intake" and "doctor advised to reduce sodium intake"), were significantly different between conditions, they were not controlled for because the labels may have differentially influenced responses to these items, because only 1 label explicitly used the word "sodium."

There were no significant differences between the 2 groups on any outcomes in Experiment 2 (Table 1). "Sodium warning" participants, however, ordered 68 fewer milligrams of sodium on average compared with "salt warning" participants. This result combined with "sodium warning" participants ordering significantly less sodium from the fast-food menu compared with the control in Experiment 1 led to testing "sodium warning" language in Experiment 3.

Experiment 3 tested the effects of sodium warning design and color. Participants (N=6,466) were recruited (4,323 from SSI, 2,143 from MTurk) and randomized to 1 of 10 label conditions (Figure 3). The black salt shaker label is currently mandated by NYC law. A large number of participants (n=1,503) were excluded because the Amazon server hosting the survey temporarily shut down during data collection. Additional participants (n=486) were excluded based on the criteria used in the previous experiments (Figure 1 and Figure 2). The final sample was balanced across conditions and included 4,477 participants (2,571 from SSI, 1,906 from MTurk) (Appendix Table 1, available online).

Experiment 3 results are presented collapsed across red and black color groups because no statistically significant differences in outcomes between red and black versions of the same labels were found (Appendix Table 2, available online).

There were no statistically significant differences in the average sodium ordered across the 6 label conditions (Table 2), but all warning label groups ordered lower-sodium meals than the control group (control mean sodium ordered: 1,532 mg, SE=26 mg), with the stop sign label (mean sodium ordered: 1,470 mg, SE=18 mg; versus control uncorrected, p=0.045; versus control corrected, p=0.630) and traffic light label (mean sodium ordered: 1,457 mg, SE=25 mg; versus control uncorrected, p=0.034; versus control corrected, p=0.510) leading to the lowest-sodium choices.

Compared with the control group, participants who saw any warning label perceived high-sodium meals to be saltier and reported a stronger belief that eating those meals often would increase their risk of high blood pressure (all p<0.001). They also estimated sodium content of high- and lower-sodium meals significantly more accurately (all p<0.001) (Table 2). Compared with the control group, the salt shaker, text, and stop sign warning labels decreased intentions to order high-sodium meals (p=0.017, p=0.002, and p=0.039, respectively), and the text and hazard sign warning labels increased beliefs that eating those meals often would increase the risk of weight gain (p=0.035 for both). Salt shaker label participants rated high-sodium meals as significantly less salty than the traffic light, text, and hazard sign labels and

Table 1. Experiments 1 and 2: Outcomes by Study Condition, Percentages, and Means (SEs)

Variable	Control	High sodium warning	High salt warning	Sodium warning	Salt warning
Experiment 1 (*n*=1,036)					
n	262	259	265	250	
Meal choice					
Average sodium ordered on both menus, mg	1,517.37 (33.52)	1,497.97 (34.00)	1,448.49 (33.41)	1,436.54 (32.26)	
Average sodium of fast-food meal, mg	**1,281.30**[d] (42.00)	1,248.11 (38.16)	1,210.49 (37.22)	**1,130.60**[a] (31.30)	
Average sodium of full-service meal, mg	1,753.44 (45.54)	1,747.84 (45.02)	1,686.49 (45.39)	1,742.48 (48.98)	
High-sodium item ordered on at least 1 menu, %	36.26 (2.98)	28.96 (2.82)	26.04 (2.70)	30.08 (2.93)	
High-sodium meal perceptions and intentions					
Delicious, 1–5	3.83 (0.06)	3.90 (0.06)	4.01 (0.05)	3.92 (0.06)	
Salty, 1–5	**3.84**[b,c,d] (0.05)	**4.12**[a,c] (0.05)	**4.35**[a,b] (0.04)	**4.19**[a] (0.04)	
Healthy, 1–5	1.86 (0.05)	1.84 (0.05)	1.72 (0.04)	1.78 (0.05)	
Purchase intentions, 1–5	3.05 (0.07)	3.07 (0.07)	3.10 (0.07)	2.94 (0.07)	
Median sodium estimate, mg	**275**[b,c,d]	**600**[a]	**625**[a]	**700**[a]	
High-sodium meal disease risk perceptions					
High blood pressure, 1–5	**4.07**[c,d] (0.05)	**4.13**[c] (0.04)	**4.30**[a,b] (0.04)	**4.23**[a] (0.05)	
Weight gain, 1–5	4.24 (0.04)	**4.17**[c] (0.05)	**4.33**[b] (0.04)	4.30 (0.04)	
Lower-sodium meal perceptions and intentions					
Delicious, 1–5	3.92 (0.06)	3.83 (0.06)	3.94 (0.06)	3.89 (0.06)	
Salty, 1–5	3.48 (0.05)	3.33 (0.05)	3.35 (0.05)	3.41 (0.04)	
Healthy, 1–5	2.67 (0.05)	2.75 (0.05)	2.73 (0.05)	2.74 (0.05)	
Purchase intentions, 1–5	3.28 (0.06)	3.19 (0.07)	3.22 (0.07)	3.21 (0.07)	
Median sodium estimate, mg	**210**[c,d]	275	**325**[a]	**400**[a]	
Lower-sodium meal disease risk perceptions					
High blood pressure, 1–5	3.47 (0.05)	3.35 (0.04)	3.35 (0.05)	3.40 (0.05)	
Weight gain, 1–5	3.44 (0.05)	3.41 (0.05)	3.45 (0.05)	3.45 (0.05)	
Knowledge					
High versus low sodium comparisons both correct, %	**25.19**[b,c,d] (2.69)	**60.23**[a] (3.05)	**56.23**[a] (3.05)	**61.60**[a] (3.08)	
High versus high sodium comparison correct, %	**61.83**[b,d] (3.01)	**47.49**[a] (3.11)	53.58 (3.07)	**48.40**[a] (3.17)	
Label use					
Noticed noncalorie label, %	**7.63**[b,c,d] (1.64)	**64.48**[a] (2.98)	**64.53**[a] (2.94)	**70.80**[a] (2.88)	
Label influenced meal choice on at least 1 menu, %	**4.96**[b,c,d] (1.34)	**32.05**[a] (2.91)	**31.32**[a] (2.85)	**37.20**[a] (3.06)	
Most helpful label					
Chose high sodium label, %	**57.63**[b,c,d] (3.06)	**69.88**[a,c,d] (2.86)	**37.74**[a,b] (2.98)	**34.40**[a,b](3.01)	
Chose high salt label, %	**19.47**[c] (2.45)	**13.51**[c] (2.13)	**44.91**[a,b,d] (3.06)	**12.80**[c] (2.12)	
Chose sodium warning label, %	**22.90**[d] (2.60)	**16.60**[d] (2.32)	**17.36**[d] (2.33)	**52.80**[a,b,c] (3.16)	

(*continued on next page*)

Table 1. Experiments 1 and 2: Outcomes by Study Condition, Percentages, and Means (SEs) (*continued*)

Variable	Control	High sodium warning	High salt warning	Sodium warning	Salt warning
Experiment 2 (*n*=665)					
n				328	337
Meal choice					
Average sodium ordered on both menus, mg				1,432.62 (28.32)	1,500.83 (28.96)
Average sodium of fast-food meal, mg				1,178.02 (30.95)	1,242.85 (32.94)
Average sodium of full-service meal, mg				1,687.23 (39.24)	1,758.81 (39.74)
High-sodium item ordered on at least 1 menu, %				25.00 (2.39)	29.97 (2.50)
High-sodium meal perceptions and intentions					
Delicious, 1–5				4.04 (0.05)	4.01 (0.04)
Salty, 1–5				4.21 (0.04)	4.22 (0.04)
Healthy, 1–5				1.73 (0.04)	1.78 (0.04)
Purchase intentions, 1–5				3.05 (0.06)	3.01 (0.06)
Median sodium estimate, mg				800	800
High-sodium meal disease risk perceptions					
High blood pressure, 1–5				4.27 (0.04)	4.20 (0.04)
Weight gain, 1–5				4.22 (0.04)	4.21 (0.04)
Lower-sodium meal perceptions and intentions					
Delicious, 1–5				3.88 (0.05)	4.00 (0.04)
Salty, 1–5				3.31 (0.04)	3.23 (0.04)
Healthy, 1–5				2.66 (0.05)	2.72 (0.04)
Purchase intentions, 1–5				3.16 (0.06)	3.24 (0.05)
Median sodium estimate, mg				422.5	450
Lower-sodium meal disease risk perceptions					
High blood pressure, 1–5				3.45 (0.05)	3.40 (0.04)
Weight gain, 1–5				3.43 (0.05)	3.40 (0.05)

Note: All values are means (SEs) unless otherwise noted. Boldface indicates statistical significance (Holm-Bonferroni-corrected $p<0.05$). Raw statistics are displayed. The high-sodium meal perceptions and intentions and disease risk perception means are averages across menu items with more than 2,300 mg of sodium. The lower-sodium meal perceptions and intentions and disease risk perception means are averages across menu items with 2,300 mg or less. Appendix (available online) provides survey questions.
[a]Statistically significantly different from control condition (Experiment 1).
[b]Statistically significantly from high sodium warning condition (Experiment 1).
[c]Statistically significantly different from high salt warning condition (Experiment 1).
[d]Statistically significantly different from sodium warning condition (Experiment 1).

Table 2. Experiments 3 (Collapsed Across Colors) and 4: Outcomes by Study Condition, Percentages, and Means (SEs)

Variable	Control	Salt shaker warning	Text warning	Hazard warning	Stop warning	Traffic light warning	Red stop warning
Experiment 3 (*n*=4,477)							
n	441	897	886	916	883	454	
Meal choice							
Average sodium ordered on both menus, mg	1,531.96 (25.69)	1,506.93 (18.28)	1,489.39 (17.33)	1,487.29 (17.01)	1,470.13 (17.75)	1,456.94 (24.83)	
Average sodium of fast-food meal, mg	1,242.43 (30.33)	1,243.56 (21.29)	1,218.86 (20.31)	1,212.37 (19.46)	1,190.77 (19.14)	1,192.09 (26.21)	
Average sodium of full-service meal, mg	1,821.50 (35.55)	1,770.30 (24.62)	1,759.92 (24.84)	1,762.21 (24.05)	1,749.48 (25.26)	1,721.78 (36.17)	
High-sodium item ordered on at least 1 menu, %	35.60 (2.28)	33.22 (1.57)	32.17 (1.57)	30.90 (1.53)	31.48 (1.56)	33.04 (2.21)	
High-sodium meal perceptions and intentions							
Delicious,1–5	3.86 (0.04)	3.83 (0.03)	3.78 (0.03)	3.84 (0.03)	3.85 (0.03)	3.91 (0.04)	
Salty, 1–5	**3.74**[b–f] (0.04)	**4.00**[a,c,d,f] (0.03)	**4.12**[a,b] (0.03)	**4.11**[a,b] (0.03)	**4.10**[a] (0.03)	**4.22**[a,b] (0.04)	
Healthy, 1–5	2.10 (0.04)	2.01 (0.03)	1.99 (0.03)	2.03 (0.03)	2.01 (0.03)	2.00 (0.05)	
Purchase intentions, 1–5	**3.19**[b,c,e] (0.05)	**2.98**[a] (0.04)	**2.94**[a] (0.04)	3.01 (0.04)	**2.99**[a] (0.04)	2.99 (0.05)	
Median sodium estimate, mg	**200**[b–f]	**1,000**[a,c–f]	**1,500**[a,b,f]	**1,350**[a,b,f]	**1,450**[a,b,f]	**1,875**[a–e]	
High-sodium meal disease risk perceptions							
High blood pressure,1–5	**3.76**[b–f] (0.04)	**4.00**[a] (0.03)	**4.08**[a] (0.03)	**4.03**[a] (0.03)	**4.08**[a] (0.03)	**4.11**[a] (0.04)	
Weight gain, 1–5	**3.92**[c,d] (0.04)	4.06 (0.03)	**4.08**[a] (0.03)	**4.08**[a] (0.03)	4.06 (0.03)	4.09 (0.04)	
Lower-sodium meal perceptions and intentions							
Delicious, 1–5	3.81 (0.04)	3.81 (0.03)	3.84 (0.03)	3.84 (0.03)	3.89 (0.03)	3.92 (0.04)	
Salty, 1–5	**3.38**[b–e] (0.04)	**3.23**[a,f] (0.03)	**3.22**[a,f] (0.03)	**3.24**[a,f] (0.03)	**3.21**[a,f] (0.03)	**3.50**[b–e] (0.03)	
Healthy, 1–5	2.87 (0.04)	2.88 (0.03)	2.92 (0.03)	2.91 (0.03)	2.93 (0.03)	2.82 (0.04)	
Purchase intentions, 1–5	3.22 (0.05)	3.20 (0.04)	3.26 (0.04)	3.22 (0.04)	3.33 (0.04)	3.28 (0.05)	
Median sodium estimate, mg	**137.5**[b–f]	**365**[a,c–f]	**500**[a,b,f]	**500**[a,b,f]	**500**[a,b,f]	**975**[a–e]	
Lower-sodium meal disease risk perceptions							
High blood pressure, 1–5	3.31 (0.04)	**3.19**[f] (0.03)	**3.17**[f] (0.03)	**3.19**[f] (0.03)	**3.19**[f] (0.03)	**3.37**[b–e] (0.04)	
Weight gain, 1–5	3.32 (0.04)	3.25 (0.03)	3.25 (0.03)	3.25 (0.03)	3.26 (0.03)	3.36 (0.04)	
Knowledge							
High versus low sodium comparisons both correct, %	**25.40**[b–f] (2.08)	**45.82**[a,e,f] (1.66)	**52.26**[a] (1.68)	**51.97**[a] (1.65)	**53.57**[a,b] (1.68)	**57.71**[a,b] (2.32)	
High versus high sodium comparison correct, %	**54.61**[c,d,f] (2.39)	**48.68**[f] (1.69)	**43.96**[a] (1.68)	**45.27**[a,f] (1.66)	**49.36**[f] (1.70)	**36.32**[a,b,d,e,f] (2.28)	
Label use							
Noticed noncalorie label, %	**11.79**[b–f] (1.54)	**44.26**[a,c–f] (1.66)	**59.82**[a,b] (1.65)	**60.92**[a,b] (1.61)	**59.12**[a,b] (1.66)	**61.67**[a,b] (2.28)	
Label influenced meal choice on at least 1 menu, %	**9.98**[b–f] (1.43)	**28.87**[a,c–f] (1.51)	**40.97**[a,b] (1.65)	**41.70**[a,b] (1.63)	**40.77**[a,b] (1.65)	**42.07**[a,b] (2.32)	
Experiment 4 (*n*=4,234)							
n	1,411					1,412	1,411
Meal choice							
Average sodium ordered on both menus, mg	**1,505.96**[h,i] (14.81)					**1,437.88**[g] (14.65)	**1,460.27**[g] (13.54)

(*continued on next page*)

Table 2. Experiments 3 (Collapsed Across Colors) and 4: Outcomes by Study Condition, Percentages, and Means (SEs) (*continued*)

Variable	Control	Salt shaker warning	Text warning	Hazard warning	Stop warning	Traffic light warning	Red stop warning
Average sodium of fast-food meal, mg	**1,252.24**[h] (17.15)					1,222.68 (16.73)	**1,193.15**[g] (15.27)
Average sodium of full-service meal, mg	**1,759.67**[i] (20.10)					**1,653.07**[g,h] (20.29)	**1,727.40**[i] (19.27)
High-sodium item ordered on at least 1 menu, %	**34.87**[h,i] (1.27)					**30.81**[g] (1.23)	**28.49**[g] (1.20)

Note: All values are means (SEs) unless otherwise noted. Boldface indicates statistical significance (Holm-Bonferroni-corrected $p<0.05$). Raw statistics are displayed. The high-sodium meal perceptions and intentions and disease risk perception means are averages across menu items with more than 2,300 mg of sodium. The lower-sodium meal perceptions and intentions and disease risk perception means are averages across menu items with 2,300 mg or less. Appendix (available online) provides survey questions.
[a]Statistically significantly different from control condition (Experiment 3).
[b]Statistically significantly different from salt shaker warning condition (Experiment 3).
[c]Statistically significantly different from text warning condition (Experiment 3).
[d]Statistically significantly different from hazard warning condition (Experiment 3).
[e]Statistically significantly different from stop warning condition (Experiment 3).
[f]Statistically significantly different from traffic light warning condition (Experiment 3).
[g]Statistically significantly different from control condition (Experiment 4).
[h]Statistically significantly different from red stop warning condition (Experiment 4).
[i]Statistically significantly different from traffic light warning condition (Experiment 4).

estimated sodium content of high- and lower-sodium meals significantly less accurately than all other warning labels. By contrast, traffic light label participants estimated both types of meals' sodium contents significantly more accurately than all other labels. Furthermore, when traffic light label participants saw lower-sodium meals that did not qualify for a warning (but were still high in sodium), they rated them as saltier, higher in sodium, and more likely to increase risk of high blood pressure compared with all other labels. Participants who saw any warning labels other than traffic light labels perceived meals without warnings to be less salty than the control.

When comparing high- versus low-sodium meals, all warning label participants correctly identified the higher sodium meal more often than control participants (all $p<0.001$). However, compared with all other warnings, the salt shaker label reduced participants' abilities to correctly identify the higher sodium meal. By contrast, when comparing 2 high-sodium meals (both with warning labels), participants who saw the traffic light, text, or hazard sign labels correctly identified the meal higher in sodium significantly less often than control participants. Furthermore, when both meals had warning labels, participants viewing traffic lights versus other labels correctly identified the higher sodium meal less often.

As expected, all warning label participants reported seeing a noncalorie label significantly more often than control participants, but salt shaker label participants remembered seeing warning labels significantly less often than the other warning label groups.

In summary, although all warning labels reduced the average sodium ordered compared with the control, none of these differences were statistically significant. All warning labels improved consumer understanding of sodium content and health risks associated with overconsuming sodium. The traffic light label appeared to be the most influential, whereas the salt shaker label was least influential.

To determine whether the observed sodium reductions would replicate and reach statistical significance in a larger sample powered to detect effect sizes from Experiment 3, Experiment 4 was preregistered (Appendix, available online) and conducted to test the top-performing labels (traffic light and red stop sign) compared with a control. Participants (N=4,601) were recruited and randomized to a control, red stop sign, or traffic light label (Figure 3). Participants were excluded (n=367) based on criteria used in the previous experiments, and for failing a cultural data integrity check included because of recent concerns about intentionally masked geo-locations on MTurk (Appendix Figure 3, available online).[25] The final sample was balanced across conditions and included 4,234 participants (Appendix Table 1, available online).

Compared with the control, the average sodium ordered in Experiment 4 across both restaurants was reduced in the traffic light (−68 mg [−4.5%], p=0.002) and red stop sign (−46 mg [−3.0%], p=0.049) groups. The traffic light and red stop sign labels also reduced the percentage of participants choosing a high-sodium item on at least 1 menu (31%, p=0.043 and 28%, p=0.001, respectively) (Table 2).

Stratifying by restaurant, traffic light label participants ordered significantly less sodium from the full-service restaurant compared with control (−107 mg [−6.1%], p<0.001) and red stop sign label participants (−74 mg [−4.3%], p=0.016). Red stop sign label participants ordered significantly less sodium from the fast-food restaurant versus control participants (−59 mg [−4.7%], p=0.033).

DISCUSSION

Four experiments were conducted to test the influence of different sodium warning label designs. In the sufficiently powered, preregistered replication (Experiment 4), traffic light and red stop sign labels significantly reduced average sodium ordered across both restaurants (by 68 mg and 46 mg, respectively), and a significantly lower percentage of traffic light and red stop sign participants ordered a high-sodium item on at least 1 menu compared with the control. In the other experiments, all warning labels consistently reduced the average sodium ordered (by 19−81 mg) versus the control, but these results were not statistically significant (possibly owing to limited statistical power). Based on the consistent replication of effects across all experiments, sodium warning labels appear to reduce average sodium ordered from restaurant menus by 3%−5%. Although such effects may appear relatively small, they may be meaningful at the population level.

Warnings also significantly changed perceptions and knowledge. All warnings improved accuracy of estimated sodium content for labeled and unlabeled meals, increased health risk and saltiness perceptions, and improved participants' abilities to identify a high- versus low-sodium meal compared with no label. Some warnings also increased the perceived risk of weight gain, despite no direct link between sodium levels and weight. This may simply be because participants generalized the warning message to a range of negative health outcomes. Because Americans are advised to reduce their sodium intake[26] but poorly understand food sodium content,[7,8] these educational outcomes are promising.

These findings align with tobacco and sugary drink research showing that text warnings affect perceptions and knowledge,[11−13] which in turn can affect behavior. Data suggest disease risk perceptions are critical determinants of behavior for diet, alcohol consumption, sun protection, and vaccines.[27−29] Additionally, evidence from restaurant calorie labeling and sugary drink warning label studies suggests nutrition labels tend to change behavioral intentions when the provided information violates expectations (e.g., learning that a salad has 1,500 calories is more influential than learning that a brownie sundae has 1,500 calories).[8,30] Because of consumers' documented lack of knowledge about sodium content,[7,8] sodium warnings may surprise consumers and subsequently affect their behavior.

There may also be ways to increase the impact of warnings on behavior. Tobacco research suggests graphic warnings could be more impactful than text warnings by increasing negative affect and cognitive elaboration,[31−34] suggesting larger sodium warnings with icons or other graphic images might be more effective. Text sodium warning labels may also more effectively change meal orders if more items were labeled (e.g., if the label threshold were 1,500 mg versus 2,300 mg). Lowering the threshold could also provide more incentive for industry reformulation but could be legally challenging in the absence of sufficient research to justify a lower threshold.[35]

Regarding differences between label designs, traffic light and red stop sign labels significantly reduced average sodium ordered compared with the control and consistently showed the largest reductions in average sodium ordered (46−76 mg). The traffic light label was also most effective at educating consumers and elicited the most accurate sodium estimates. By contrast, the salt shaker label elicited the least-accurate sodium estimates, worst performance on the labeled versus unlabeled comparison task, lowest reported noticing and use of the label, and lowest (nonsignificant) reduction in sodium ordered (25 mg). This makes intuitive sense, as the salt shaker label had the least amount of information (no warning text next to the symbol, unlike all other designs), whereas the traffic light had the most information (2 thresholds for sodium). This tracks with front-of-package studies that have found traffic light labels to be particularly effective at increasing attention and identification of healthier options.[36−39] It is also possible that the intuitive nature of the traffic light design (red means stop, green means go) was easier for participants to understand. The stop sign label's strong performance could be similarly explained by automatic associations with stopping.[40] These results are consistent with a recent study that found octagonal sugary drink warning labels with the word “warning” increased perceived message effectiveness compared with labels without these characteristics.[41] Although the traffic light design appears to be most effective overall, there may be legal barriers and implementation challenges in mandating a design with multiple thresholds.[35]

The results suggest that adding warning text next to a symbol is likely to improve consumer understanding of the label, as illustrated by the salt shaker label—the only label without explanatory text—performing worse than other labels on secondary outcomes. This was true even when compared directly with the hazard sign symbol with text, which had the same shape as the salt shaker label. Results from the first experiment suggest that “sodium warning” text may be more effective than “high salt” or “high sodium,” potentially because “high in. . .” is frequently used in positive health claims,[42] but this requires further study. The experiments did not reveal meaningful differences in using the word “salt” versus “sodium” on a warning label, and there were no statistically significant differences between red and black labels across outcomes. This is not entirely surprising, as previous research has found contradictory results on the effectiveness of red versus black warnings for food, alcohol, road signs, and chemical hazards.[42−45]

Although warning labels generally improved consumer knowledge, there were 2 instances in which they may have confused participants. First, all Experiment 3 label groups (except traffic light) rated unlabeled items as less salty than the control, despite these items containing large amounts of sodium. Nonetheless, there was no evidence that these participants ordered meals higher in sodium. Second, when participants in any warning condition had to choose between 2 meals—1 labeled and 1 unlabeled—they were typically able to correctly identify which was higher in sodium based on the presence of a label. When both meals were labeled, however, warning label participants were worse at identifying the higher sodium meal compared with control participants who never saw warning labels. This might be because the warning label participants were more likely than control participants to notice calorie labels because they appeared near the sodium warnings, and to use calories as a proxy for sodium because the warnings no longer conveyed enough information to distinguish between the 2 meals. It is possible that warning label participants—who were more likely to notice calorie labels—assumed the meal with more calories was higher in sodium, which is usually a good rule of thumb, but in this instance was not true. Further research is needed to understand whether sodium warning labels promote the use of calorie labels.

This study had several strengths. This is the first study, to the authors’ knowledge, to examine the influence of a range of sodium warning labels on behavioral intentions and perceptions. Effects were replicated across experiments with demographically different samples. The third experiment’s sample was racially, ethnically, and educationally diverse. Finally, a variety of label designs were tested across a range of outcomes.

Limitations

This study has several limitations. First, it measured hypothetical (not actual) choices, and warning labels might have been more salient when viewing a menu in an online context. This setting may have also introduced a social desirability bias to select healthier options, although this is unlikely given participant anonymity. These experiments also only examined a one-time exposure to the labels. Future research should test the study’s best-performing warning labels within high-risk subpopulations trying to reduce sodium intake, explore how in-person, repeated exposure to warning labels influences behavior and perceptions, and evaluate the effect of sodium warning labels on industry reformulation, which could greatly influence sodium consumption.[46]

CONCLUSIONS

Traffic light and red stop sign sodium warning labels significantly reduced sodium ordered by 3%−5% in a hypothetical menu choice task. Although small, effects of this size may be beneficial at a population level. Warning labels also increased knowledge about high-sodium content in restaurant meals. Designs with “sodium warning” text are likely to improve consumer understanding.

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SUPPLEMENTAL MATERIAL

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