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REGULAR ARTICLE

A Brief Motivational Intervention Differentially Reduces Sugar-sweetened Beverage (SSB) Consumption

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Abstract

Background Environmental and behavioral interventions hold promise to reduce sugar-sweetened beverage (SSBs) consumption.

Purpose To test, among frequent SSB consumers, whether motivations to consume SSBs moderated the effects of (a) a workplace SSB sales ban (environmental intervention) alone, and (b) a "brief motivational intervention" (BI) in addition to the sales ban, on changes in SSB consumption.

Methods We assessed whether (1) baseline motivations to consume SSBs (craving, psychological stress, or taste enjoyment) impacted changes in daily SSB consumption at 6-month follow-up among frequent (>12oz of SSBs/day) SSB consumers ($N = 214$); (2) participants randomized to the BI ($n = 109$) versus to the sales ban only ($n = 105$) reported greater reductions in SSB consumption at follow-up; and (3) motivations to consume SSBs moderated any changes in SSB consumption.

Results In response to the sales ban alone, individuals with stronger SSB cravings (+1 *SD*) at baseline showed significantly smaller reductions in daily SSB consumption at 6-month follow-up relative to individuals with weaker (−1 *SD*) SSB cravings (2.5 oz vs. 22.5 oz), $p < .01$. Receiving the BI significantly increased reductions for those with stronger SSB cravings: Among individuals with stronger cravings, those who received the BI evidenced significantly greater reductions in daily SSB consumption [$M(SE) = -19.2$ (2.74) oz] than those who did not [$M(SE) = -2.5$ (2.3) oz, $p < .001$], a difference of 16.72 oz.

Conclusions Frequent SSB consumers with stronger SSB cravings report minimal reductions in daily SSB consumption with a sales ban only, but report greater reductions if they also receive a motivational intervention. Future multilevel interventions for institutions should consider both environmental and individualized multi-level interventions.

Clinical Trial information NCT02585336.

Keywords Craving strength · Environmental intervention · Brief intervention · Sugar-sweetened beverages

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Introduction

Sugar-sweetened beverages (SSBs), defined as sodas, sports/energy drinks, "fruit drinks" such as fruit-flavored drinks that are not 100% fruit juice, and sweetened teas and coffees, account for 34% of added sugar in the American

diet [1]. The scientific community has reached a consensus that decreasing SSB consumption can reduce the prevalence of chronic metabolic diseases [2] such as Type 2 diabetes and obesity. The analyses reported in this manuscript examine the combined effects of environmental and counseling interventions for frequent SSB consumers.

Environmental interventions targeting reduced SSB consumption limit or alter access to SSBs [3]. These "food environment" interventions have largely been tested in schools [4, 5], hospitals [6], and private employment workplaces [7]. For example, one such intervention banned the sale of SSBs and resulted in an overall reduction in both employee SSB consumption and improvements in employee metabolic health. The effectiveness of these interventions may depend on characteristics of the target population. Indeed, although some individuals who consume SSBs due to convenience or cost may no longer consume them once they become more expensive [8], others may consume SSBs as a result of individual differences in behavior patterns, such as experiencing strong cravings, coping with stress, or deriving high levels of taste enjoyment from SSBs. Thus, although changes to the environment may reduce SSB consumption for many individuals, multilevel interventions may be necessary to optimally address diverse motivations (e.g., cravings, coping with stress) for SSB consumption and heterogeneous responses to SSB reduction efforts.

Clarifying which types of interventions are most effective for changing health behaviors for different people ("treatment matching") is a key priority of the National Institutes of Health Precision Medicine Initiative. Here, we review three possible individual differences that may moderate intervention outcomes.

Craving

Some individuals may consume SSBs in response to cravings. A large and hotly-debated literature speaks to the arguably addictive-like aspects of sugar, the primary source of calories in SSBs [9, 10]. Although most of these studies have used animal models [9, 11–13], they have demonstrated associations between SSB consumption and behavioral evidence of craving. Emerging research suggests that, unlike the whole foods (e.g., fruits) from which they may be derived, SSBs (e.g., fruit-flavored drinks) can elicit reward and craving responses that could precipitate continued use despite environmental constraints on availability [14]. Most observations focused on craving-related behavior involving SSBs have used adolescent samples [15, 16], highlighting the need for research on SSB consumption behaviors across the lifespan. For example, one trial found that adolescents with overweight or obesity experienced withdrawal symptoms, including increased cravings, upon cessation of SSB consumption [15]. Research in adult populations does, however, suggest that adults have greater difficulty controlling their intake of sugared (not diet) soda, relative to other foods and beverages [17]. Thus, intervening on craving experiences may be one important strategy in the pursuit of reducing SSB consumption.

Stress

Other individuals may consume SSBs to cope with stress. Consuming SSBs to cope with psychological stress is a form of "comfort eating," a behavior that commonly involves consuming highly palatable foods and drinks in the pursuit of reducing negative affect [18]. Comfort eating consistently reduces physiological and behavioral stress responses (most research to date being in animal models), and some human studies suggest that comfort eating may reduce negative mood [18–22]. The rewarding properties of tasty foods, such as SSBs, may be heightened in times of stress [23]. Thus, people may consume SSBs to cope with stress, and interventions that train adaptive coping behaviors may be another important target in the pursuit of reducing SSB consumption.

Taste enjoyment

SSBs are engineered to be hyperpalatable [24], hence it is unsurprising that many people consume SSBs for sheer taste enjoyment. Children [25] and adolescents [26] cite taste as the most important factor in determining their SSB intake, and research has documented how consumptive behavior adopted during early developmental periods predicts SSB consumption [27] and health [28, 29] later in childhood/adolescence and into adulthood. More limited data also suggest that adults identify taste preference as important in their SSB consumption decisions [30], and other data document that adults who endorse non-diet soda consumption report doing so due to superior taste of regular SSBs (as opposed to diet or other zero-calorie beverages) [31].

The present study

Given literature linking self-reported craving levels [32], use of food to cope with stress [18, 23, 33], and taste enjoyment [26, 34, 35] to increased consumption of highly palatable food and/or drinks, we explored the effects of an environmental intervention in the form of a workplace SSB sales ban, and [36] the effects of a brief motivational intervention (BI) on SSB consumption among individuals with varying levels of these three SSB consumptive tendencies. Specifically, we evaluated how the effectiveness of our interventions varied by these three motivations to consume SSBs (craving, psychological stress, and degree

of taste enjoyment), and examined how these motivations predicted response to the SSB sales ban and BI.

Methods

Participants

We engaged potential participants from a pool of University of California, San Francisco (UCSF) employees (staff and faculty) who responded to an initial employee survey on SSB consumption (N = 2,556). The employee survey was first sent online (Qualtrics) and in hard copy on June 25, 2015, to be completed at any time prior to November 1, 2015. Employees completed the survey in English, Spanish, or Chinese. We compensated each employee who completed this survey with a $25 gift card to accessible retail stores.

We screened 699 survey respondents who endorsed consuming at least 12 ounces of SSBs daily ("frequent SSB consumption") for potential randomization to receive the BI. Eligible participants were full-time employees at UCSF who did not have definitive plans to leave UCSF. We excluded participants who did not speak English, who reported prior diagnosis of Type 1 or 2 diabetes, who were pregnant or nursing, who were unwilling or unable to complete a morning fasted blood draw, who regularly worked night shifts, or who worked at a different campus than the clinic site. Of these 699 initial screener respondents, 214 were eligible and interested in participation, and were randomized to the BI (n = 109) or the control group (n = 105).

Workplace SSB Sales Ban

UCSF implemented an environmental intervention on November 1, 2015 in the form of a workplace SSB sales ban such that no UCSF vendor could continue to sell SSBs [37]. This intervention impacted the workplaces for all participants in this study.

Procedures

Assessments

We conducted baseline assessments of eligible participants during the four months prior to the complete implementation of a university-wide workplace SSB sales ban. Participants attended an in-person assessment wherein they completed questionnaires, a fasted blood draw, and height and weight measurements, and were randomized to the BI or control group by trained study staff. Participants completed an online questionnaire at 6 months post-baseline to assess changes in SSB consumption, and attended a second in-person assessment 10 months after their initial clinic visit, as described elsewhere [8].If randomized to the control group, participants completed assessments but did not receive the brief intervention. We compensated all participants with $50 for the baseline assessment and $75 for the second assessment.

Intervention

Study staff used a computer-generated program that performed block randomization such that participants received "control" or "brief intervention" (BI). If randomized to the BI, participants completed a brief (~15 min) motivational interview with a trained health educator. The interview used an adapted version of a standard brief alcohol misuse intervention [38]. During the intervention session, the health educator demonstrated the amount of sugar in the SSBs that the participant reported consuming each day by placing sugar cubes in a cup. The health educator also provided information about the risks of high sugar intake and the benefits of reducing sugar intake, assisted the participant in setting a health behavior goal related to SSB consumption, and provided the participant with written materials and a link to a 30-min video about the role of sugar in a healthy diet (see Appendix 1). Health educators made brief (~5 min) booster telephone calls to revisit participants' SSB consumption goals one week later, as well as at two weeks and six months post-implementation of the SSB sales ban.

Measures

Motivations for consuming SSBs

We assessed reasons for consuming SSBs at participants' baseline visit.

Craving strength

We assessed consuming SSBs due to SSB cravings by asking participants, "*At its most severe point, how strong was your craving for a drink with sugar in it today?"* and asking them to respond on a 7-point Likert scale ranging from "*none at all"* (coded as 1) to "*strong urge and would have drunk a sugar-sweetened beverage if it were available"* (coded as 7).

Stress

We asked about consuming SSBs due to stress by prompting participants, "*Thinking about all of these drinks with added sugar, how often do you have them because you…*" and then asking them to rate the extent to which they consumed SSBs because they "*are stressed out*." Participants responded by endorsing: *frequently* ("high"), *sometimes* ("medium"), or *never* ("low").

Taste enjoyment

We asked about consuming SSBs due to taste enjoyment by prompting participants, "*Thinking about all of these drinks with added sugar, how often do you have them because you…*" and then asking them to rate the extent to which they consumed SSBs because they "*enjoy the taste.*" Participants responded by endorsing: *frequently* ("high"), *sometimes* ("medium"), or *never* ("low").

SSB intake

We assessed SSB intake using a 15-item version of a beverage intake questionnaire [39]. Participants reported the frequency of consuming specific types of beverages on a typical day, including regular/non-diet soda, diet soda, 100% fruit juice, "fruit" drinks (SSBs that contain fruit juice or flavorings, such as lemonade or smoothies), sports or energy drinks, coffee or tea drinks (e.g., Arizona iced tea, Frappuccino drinks), and plain or zero-calorie flavored water. Of note, sugarless beverages that participants endorsed in this questionnaire, including diet sodas, unsweetened teas, and plain or zero-calorie flavored water, are not included in the computation of the SSB variable. Participants also reported how much (oz) they consumed at each occasion. We computed daily consumption (oz) for each beverage type by multiplying the frequency of consumption and serving size. Participants completed this measure at baseline and 6 months.

Analytic Plan

Covariates

We assessed several sociodemographic factors including race/ethnicity, age, job class, biological sex, place of birth, and primary language spoken at home. In these analyses, we included participant job class, age, and biological sex as covariates. Because of documented associations between BMI and SSB consumption [40, 41], BMI and craving [32, 42], and because of varying associations between BMI and stress [43–45], we also completed analyses accounting for BMI in addition to the aforementioned covariates.

Variable preparation

We analyzed SSB consumption in fluid ounces per day, age as continuous (years), biological sex as dichotomous (male or female), BI randomization as dichotomous (0 = "control," 1 = "intervention"), and job class as a categorical variable (see Table 1 for all categories). For the mean comparisons in Table 2, we divided SSB cravings into tertiles (high, medium, and low) such that it matched the other two motivation variables (stress, taste enjoyment), which had three levels. For the regression analyses, we use the continuous versions of these variables.

Model specifications

We first explored the effects of the SSB sales ban on SSB consumption at the highest and lowest levels of each motivation (craving strength, psychological stress, and degree of taste enjoyment) at baseline, and tested for between-group differences. Next, we used paired-samples *t*-tests

Table 1. Participant descriptive information

Study variable (metric)	Baseline	Follow-up (X months)
Participants randomized to motivational intervention (*n*, %)	109 (51)	99 (49)* (10 months)
Age (*M*, *SD*)	41.2 (11.0)	
Biological Sex (*n*, %)	Female 124 (57.9) Male 90 (42.1)	
Race/Ethnicity (*n*, %)		
White	47 (22.0)	
Black/African–American	32 (15.0)	
Asian-American	58 (27.1)	
Hispanic/Latino/a	42 (19.6)	
Other/Unknown	35 (16.4)	
Income (*n*, %)		
<$30,000	8 (3.7)	
$30,000–59,999	68 (31.8)	
$60,000–99,999	56 (26.2)	
$100,000–149,999	33 (15.4)	
>$150,000	27 (12.6)	
Prefer not to say	22 (10.3)	
Job Class (*n*, %)		
Medical technician	26 (12.2)	
Support clerk	43 (20.1)	
Service maintenance	77 (36.0)	
Medical	17 (7.9)	
Academic	8 (3.7)	
Other	43 (20.1)	
Motivation for SSB, *craving strength* (*M*, *SD*)	2.4 (1.5)	2.3 (1.5) (10 months)
Motivation for SSB, *stress* (*M*, *SD*)	2.4 (0.7)	2.5 (0.7) (6 months)
Motivation for SSB, *taste enjoyment* (*M*, *SD*)	1.6 (0.7)	1.7 (0.6) (*N* = 168) (6 months)

Note. *See participant descriptives and retention for participant attrition information. As reported elsewhere and above, participants randomized to receive the BI (vs. not) did not significantly differ on age, biological sex, or job class. As noted in the text, participants did not significantly differ in their motivations to consume SSBs (psychological stress, or taste enjoyment). Participants randomized to receive the BI (vs. not) had slightly lower motivations to consume SSBs due to craving compared to those in the control group [BI *M*(*SE*) = 2.2 (0.1); Control *M*(*SE*) = 2.6 (0.1); *p* = .04]. BI brief motivational intervention; SSB sugar-sweetened beverage.

Table 2. Paired-samples *t*-tests contrasting 6-month change in sugar-sweetened beverage (SSB) consumption between participants in the upper and lower tertiles (craving strength) and top and bottom categories (stress and taste enjoyment) at baseline across all participants

Predictor	*N*	Mean (*SD* or *SE*) baseline, ounces/day	Mean (*SD* or *SE*) post, ounces/day	M Diff (*SD* or *SE*), ounces/day	*t*	*p*
Craving strength						
Highest Tertile	48	37.33 (*SD*: 27.70)	29.95 (*SD*: 24.25)	−7.38 (*SD*: 34.42)	1.49	.072
Lowest Tertile	77	31.05 (*SD*: 25.80)	10.91 (*SD*: 13.44)	−20.15 (*SD*: 26.75)	6.61	<.001
Between-Group Difference		6.28 (*SE*: 4.88)	19.04 (*SE*: 3.37)	12.76 (*SE*: 5.50)	2.32	.022
Stress						
Frequently	26	40.16 (*SD*: 28.79)	23.17 (*SD*: 22.28)	−16.99 (*SD*: 37.75)	2.29	.015
Never	97	30.32 (*SD*: 24.20)	14.30 (*SD*: 15.53)	−16.02 (*SD*: 26.36)	5.99	<.001
Between-Group Difference		9.84 (*SE*: 5.57)	8.87 (*SE*: 3.79)	1.0 (*SE*: 6.4)	0.20	.90
Taste enjoyment						
Frequently	93	38.71 (*SD*: 25.74)	21.63 (*SD*: 20.80)	−17.08 (*SD*: 27.88)	5.90	<.001
Never	19	25.15 (*SD*: 31.44)	5.86 (*SD*: 7.20)	−19.29 (*SD*: 31.58)	2.66	.008
Between-Group Difference		13.56 (*SE*: 6.74)	15.77 (*SE*: 4.85)	2.2 (*SE*: 7.2)	-.30	.80

to assess changes in SSB consumption from baseline to 6 months for high and low levels of each motivation.

We then examined differential effects of the SSB sales ban only ("control") versus the SSB sales ban with the BI. In keeping with calls for presenting models free of covariates [46], we first computed three unadjusted individual multiple regression models (one model for each motivation). The primary outcome was change in SSB consumption from baseline to 6 months, with baseline SSB consumption as a covariate. Predictors in each model included the continuous motivation variable (a 3-point scale for taste enjoyment and stress and a 7-point scale for craving), intervention randomization (0 or 1), and the interaction of a predictor and intervention randomization. We then computed adjusted models that included age, biological sex, and job class as covariates. If an interaction term was statistically significant ($p < .05$), we examined simple slopes at high and low values of the moderator variable (we treated each motivation as the moderator in a given model). Predicting change scores while also accounting for a baseline value facilitates interpretation of effect sizes; however, we repeated each regression model using a residualized technique (i.e., predicting SSB consumption at follow-up) while accounting for baseline SSB consumption as a covariate, as recommended in the statistical literature [47].

We report the results of two-sided tests by including betas, standard errors, *t*-values, *p*-values, and 95% confidence intervals, as appropriate for each statistical test. We report effect sizes as change in SSB consumption in ounces per day from baseline to 6 months, as ounces of SSB consumption can be maximally compared to previously published data.

Results

Participant Characteristics and Retention

Participant demographics and pre- and post-SSB sales ban implementation values for all study variables appear in Table 1. Participant flow through the study appears in Figure 1. See Epel and colleagues for additional participant details. Complete pre-post data were available for 185 of the initial 214 participants (86%). Among those eligible for retention ($n = 200$; due to $n = 14$ discontinuing the study), we collected post-SSB sales ban implementation data from 185 participants (93%). Participants randomized to receive the BI (vs. not) had slightly less motivation to consume SSBs due to cravings compared to those in the control group [Intervention $M(SE) = 2.2$ (0.1); Control $M(SE) = 2.6$ (0.1); $p = .04$], but did not differ in terms of SSB consumption motivated by taste enjoyment

[Intervention $M(SE)$ = 1.6 (0.1); Control $M(SE)$ = 1.5 (0.1); p = .33], or psychological stress [Intervention $M(SE)$ = 2.4 (0.1); Control $M(SE)$ = 2.4 (0.1); p = .86]. Of the participants randomized to receive the BI, 99 (91%) completed the booster call at 1-week follow-up; 91 (83%) completed the booster call at 2-week follow-up; and 91 (83%) completed the booster call at 6-month follow-up. Of note, documentation was not available for two participants at all three occasions; we therefore assumed that they did not complete these calls. BMI did not significantly differ across high versus low levels of each of the motivations (Appendix 1). As previously reported, we observed a significant main effect of the SSB sales ban on SSB consumption: On average, participants reduced SSB intake from 35 oz per day to 18 oz per day (48.5%).

Effects of Environmental Intervention Stratified by Motivation Type and Level

As shown in Table 2, the SSB sales ban exerted similar effects on participants who consumed SSBs with high and low levels of psychological stress and taste enjoyment, and these effects did not significantly differ across groups. The SSB sales ban was associated with statistically significant reductions in daily SSB consumption among participants low in craving strength [$M(SD)$ reduction = 20.1 (26.7) oz, $p < .001$], and trended toward exerting a similar effect among those high in craving strength [$M(SD)$ reduction = 7.4 (34.4) oz, p = .07]. The sizes of these effects were significantly different, such that participants with lower craving strength had significantly greater reductions in SSB consumption relative to those higher in craving strength [$M(SE)$ difference = 12.8 (5.5) oz, p = .02. Thus, the removal of SSBs from the environment had a larger effect for individuals with low (relative to high) craving strength (Table 2).

Predicting Change in SSB Consumption From Motivations for Consuming SSBs and Whether or not an Individual Received the BI

Craving

As shown in Table 3, BI randomization interacted with craving strength to predict changes in SSB consumption (overall model R^2 = .67; ω^2 for the interaction = 0.04). The pattern and statistical significance of the interaction term remained without covariates in the model (see Appendix 2) and also when including BMI in addition to covariates (see Appendix 3). Deconstruction of this interaction revealed that, in response to the sales ban alone, individuals with stronger SSB cravings (+1 *SD*) at baseline showed significantly smaller reductions in daily SSBs at 6-month follow-up relative to individuals with weaker (−1 *SD*) SSB cravings (2.49 oz vs. 22.48 oz), $p < .01$ (see Figure 2). Deconstruction of this interaction further revealed that among participants higher in craving strength (+1 *SD*), those randomized to the BI evidenced significantly greater reductions in daily SSB consumption [$b(SE)$ = −19.21 (2.74)] relative to those not randomized to the BI [$b(SE)$ = −2.49 (2.33)], M diff(SE) = −16.72 (3.65), t = −4.59, $p < .001$. Specifically, among participants with higher craving strength (+1 *SD*), participants randomized to the BI reduced their SSB intake by 16.72 ounces more than did participants not randomized to the BI.

Stress

As shown in Table 3, BI intervention randomization did not interact with consuming SSBs due to stress [$b(SE)$ = 1.26 (3.86), p = .75] to predict changes in SSB consumption. This finding is held without covariates in the model (see Appendix 2) and also when including BMI in addition to covariates (see Appendix 3).

Taste enjoyment

As shown in Table 3, BI intervention randomization did not interact with consuming SSBs due to taste enjoyment [$b(SE)$ = 1.70 (4.15, p = .68] to predict changes in SSB consumption. This finding is held without covariates in the model (see Appendix 2) and also when including BMI in addition to covariates (see Appendix 3).

Discussion

Workplace SSB sales bans are a novel strategy for altering food environments: By reducing SSB availability, they hold promise for reducing consumption at the population level. However, when behaviors are craving-driven, individuals may need more individual support as well. Analyses we report here highlight the importance of implementing multilevel interventions that provide additional components for individuals with greater risk factors for the target risk behavior. This study demonstrated that a multilevel intervention was more effective than a sales ban alone in reducing SSB consumption among individuals who experience stronger baseline SSB cravings: Individuals who endorsed strong SSB cravings and who received the brief intervention reported significantly larger (−16.72 ounces) decreases in SSB consumption than their counterparts who did *not* receive the brief intervention.

Relative to those with weaker SSB cravings, those with stronger SSB cravings had a weaker response to an environmental change in the form of a workplace SSB sales ban. Individuals with stronger SSB cravings primarily had meaningful reductions in SSB consumption if they also received a brief motivational intervention. Thus, adding BIs to environmental interventions may promote

Table 3. Three models predicting changes in SSBs

M#	Predictor	*b* (*SE*)	*t*	*p*	95% CI [LB, UB]
1	Constant	2.22 (6.73)	0.33	.74	[−11.07, 15.50]
	Age	−0.11 (0.12)	−0.94	.35	[−3.97, 6.27]
	SSB (baseline)	−0.83 (0.05)	−16.38	.00	[−0.93, −0.73]
	Biological sex (male)	1.15 (2.59)	0.44	.66	[−3.97, 6.27]
	Job category				
	Support clerk	3.50 (4.35)	0.80	.42	[−5.08, 12.07]
	Service maintenance	4.80 (4.21)	1.14	.26	[−3.51, 13.11]
	Medical	0.45 (5.44)	0.08	.94	[−10.29, 11.18]
	Academic	−5.92 (7.00)	−0.85	.40	[−19.73, 7.89]
	Other	2.94 (4.44)	0.66	.51	[−5.81, 11.69]
	BI randomization	2.13 (4.76)	0.45	.66	[−7.27, 11.52]
	Craving strength	6.66 (1.25)	5.77	.00	[4.39, 8.94]
	BI randomization × craving strength	−4.83 (1.69)	−2.86	.01	[−8.17, −1.49]
2	Constant	28.38 (8.40)	3.38	.00	[11.81, 44.95]
	Age	−0.07 (0.14)	−0.53	.59	[−0.34, 0.20]
	SSB (baseline)	−0.83 (0.06)	−14.17	.00	[−0.95, −0.72]
	Biological sex (male)	−1.72 (2.89)	−0.59	.55	[−7.43, 3.99]
	Job category				
	Support clerk	3.48 (4.80)	0.72	.47	[−5.99, 12.95]
	Service maintenance	5.09 (4.76)	1.07	.29	[−4.31, 14.50]
	Medical	3.29 (5.97)	0.55	.58	[−8.48, 15.07]
	Academic	−4.14 (7.72)	−0.54	.59	[−19.39, 11.10]
	Other	2.37 (4.87)	0.49	.63	[−7.25, 11.99]
	BI randomization	−12.82 (7.18)	−1.78	.08	[−26.99, 1.36]
	Taste enjoyment	−6.39 (2.91)	−2.20	.03	[−12.13, −0.65]
	BI randomization × taste enjoyment	1.70 (4.15)	0.41	.68	[−6.49, 9.89]
3	Constant	27.85 (8.98)	3.10	.00	[10.12, 45.58]
	Age	−0.08 (0.14)	−0.58	.56	[−0.35, 0.19]
	SSB (baseline)	−0.82 (0.06)	−13.94	.00	[−0.94, −0.71]
	Biological sex (male)	−0.72 (2.90)	−0.25	.81	[−6.45, 5.01]
	Job category				
	Support clerk	4.08 (4.84)	0.84	.40	[−5.46, 13.62]
	Service maintenance	4.92 (4.80)	1.03	.31	[−4.55, 14.38]
	Medical	4.46 (5.99)	0.74	.46	[−7.36, 16.27]
	Academic	−1.97 (7.75)	−0.25	.80	[−17.27, 13.33]
	Other	2.76 (4.92)	0.56	.56	[−6.95, 12.48]
	BI randomization	−13.47 (9.68)	−1.39	.17	[−32.57, 5.64]
	Stress	−4.36 (2.60)	−1.67	.10	[−9.49, 0.78]
	BI randomization × stress	1.26 (3.86)	0.33	.75	[−6.37, 8.89]

Note. M# model number; age in years; BI brief motivational intervention coded as 0 (did not receive BI) and 1 (received BI); SSB sugar-sweetened beverage consumption, in ounces/day; biological sex coded as 0 (female) and 1 (male).

greater health behavior change among those who experience SSB cravings.

We observed meaningful reductions in SSB consumption in a workplace environment and a majority-minority participant sample. Additionally, this study targeted frequent SSB consumers (>12 oz daily), indicating that these interventions can be effective with those who are most at risk for developing negative health outcomes associated with increased added sugar intake. These results highlight the utility of developing multilevel interventions to promote health behavior. Indeed, combinations of interventions, such as point-of-purchase interventions

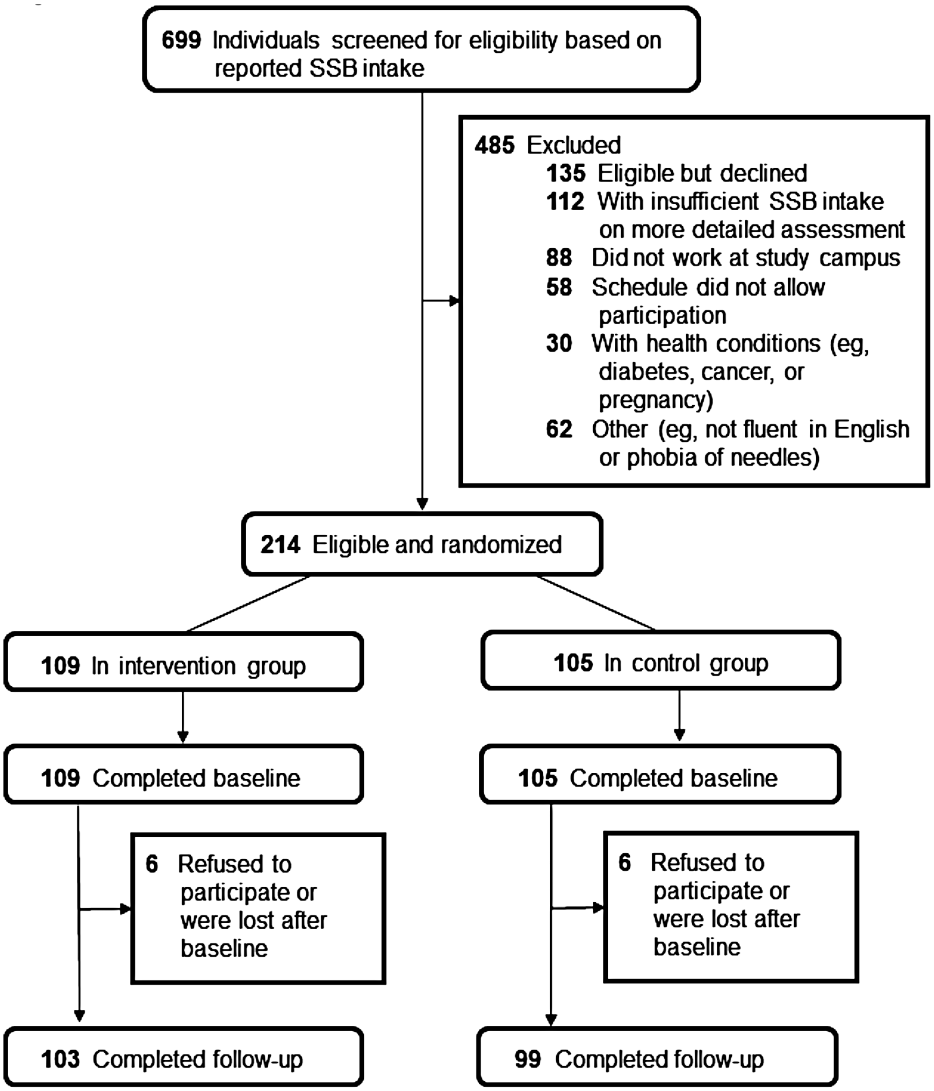

Fig. 1. *Note.* CONSORT diagram depicts common reasons for ineligibility. Please see Epel and colleagues (2019) for fuller descriptive detail of participant flow through the study.

and financial incentives, have begun to show promise in reducing SSB consumption [38].

The combination of an environmental intervention (banning the sale of SSBs) and a behavioral intervention (targeting habit-based consumptive behavior with a brief intervention) may have been particularly potent for individuals who struggle with SSB cravings for several reasons. The environmental intervention alone reduced the number of cues to which participants were exposed. Cues are strong instigators of craving experiences [32], and reducing cue exposure for individuals who are trying to make adaptive health changes despite their tendencies to experience strong cravings may be a key lever in facilitating change [48]. Food cue reactivity is a conditioned process that is difficult to change [49, 50], and together, food cue reactivity and craving predict weight gain [32]. These analyses demonstrated that removing food cues alone was not enough; the addition of the motivational intervention was critical for this high-risk group.

Although craving is typically identified in the substance misuse literature as associated with substance use and as a predictor of relapse [51, 52], there is a dearth of information regarding the role of craving as a moderator of treatment outcomes in the realm of eating behavior. It is notable that in this case, greater craving predicted larger reductions in SSB consumption, as this contrasts with literature documenting greater baseline craving as a predictor of greater substance use. For example, greater baseline alcohol craving has been associated with greater relapse among individuals identified as alcohol-dependent [53], and some data suggest that greater baseline craving has been associated with poorer outcomes in smoking cessation trials [54]. Targeting SSB reductions differs from targeting abstinence, which is often the focus in alcohol nicotine interventions.

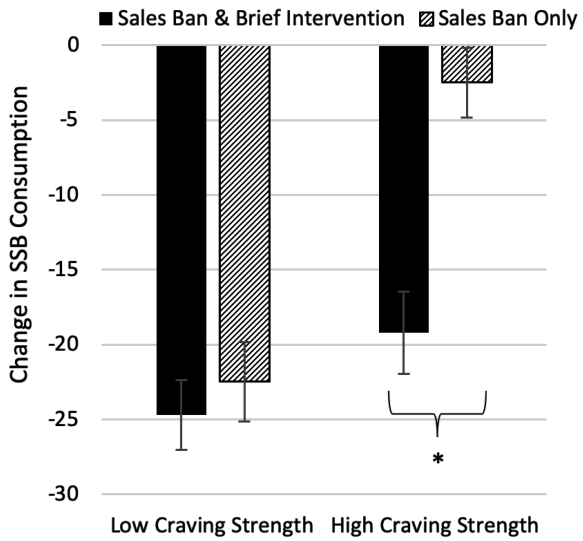

Figure 2. *Note*. * Indicates statistically significant difference ($p < .05$). "Low" and "high" are defined as one standard deviation below and above the mean, respectively. Values represent changes in daily SSB consumption from baseline to 6 months after accounting for baseline sugar-sweetened beverage (SSB) consumption (Model 1, Table 3).

Interventions targeting SSB reduction therefore may represent a unique case: Identifying individuals with greater craving and delivering an intervention that includes both environmental modification (a sales ban) and behavioral components (motivational interventions and psychoeducation), with a goal of reduction, rather than abstinence, can promote health.

BMI did not impact the pattern or statistical significance of the moderating effect of craving strength on randomization to the brief intervention on SSB consumption. This is notable given the documented associations between BMI and craving [32] and BMI and SSB consumption [40, 41]. This pattern of results suggests that the craving was an individual difference factor—regardless of BMI—that was associated with a reduction in SSB consumption following a brief intervention.

Psychological stress did not moderate the effects of the brief intervention on SSB consumption. Psychological stress shows mixed associations with consumptive behavior, with some individuals consuming more calories and some consuming fewer calories during stressful times [55]. Indeed, stress and weight gain over time also show mixed associations, with certain types of stress being associated with weight change and others not [44]. Future research should assess the types of stress that participants experience and articulate questions about stress-related consumptive behavior using scales that capture increased and decreased consumptive behavior, such as the Salzberg Stress Eating Scale [56].

Taste enjoyment did not moderate the effects of the brief intervention on SSB consumption: Participants both higher and lower in taste enjoyment significantly reduced their SSB consumption. Both SSBs [23] and their calorie-free counterparts [57], such as flavored waters and diet sodas, are engineered to be particularly tasty. Thus, it is possible that participants who reported consuming SSBs for taste enjoyment, regardless of the degree of enjoyment, were able to substitute an artificially sweetened option and thereby reduce their SSB consumption.

Limitations

These analyses are limited by several study design features. First, due to time constraints of the execution of the SSB sales ban, we were unable to recruit a control comparator at an institution *without* an SSB sales ban in place. Targeting participants with higher scores on outcomes at baseline raises concerns about regression to the mean. However, we saw a relatively small reduction in SSB consumption among participants with high cravings who did not receive the BI, suggesting that the addition of the BI was a true causal factor. Self-report measures in the context of consumptive behavior present meaningful interpretive challenges [58] and are subject to issues of social desirability bias. Additionally, these self-report items were single-item measures, which have both strengths (e.g., face validity, brevity) and weaknesses (e.g., psychometric issues). Our prior analyses with this sample, however, demonstrated correlations between reductions in SSB consumption and improvement in blood-based biomarkers of metabolic health [33], suggesting that those who self-report reductions in SSB consumption are in fact reducing such consumption to some degree. This study took place among university employees at a major medical research center, which may limit generalizability. Moreover, in this study, at least some participants may have seen SSB reduction as congruent with their work and values. Interventions in other settings may require a different presentation or additional tailoring to have similar effects. Additionally, we did not verify whether participants had actually watched the intervention video material. The primary intervention component was the in-person BI provided at baseline; the study design precludes our ability to assess the independent effect of the brief (~5 min) booster phone call sessions on SSB consumption at 6 months. Future studies could include more frequent assessments of SSB consumption so as to examine intervention components independently. Finally, our study took place at a single institution; similar research will be needed in a variety of settings in order to determine generalizability.

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Compliance with Ethical Standards

Authors' Statement of Conflict of Interest and Adherence to Ethical Standards Dr. Lustig reported writing two books for the public on metabolic disease and health, *Fat Chance* and *The Hacking of the American Mind*; neither of these books is related to the work encompassed by this manuscript. Drs. Epel and Schmidt reported receiving grants from University of California Office of the President, University of California San Francisco Office of the Executive Vice Chancellor/Provost, University of California San Francisco School of Medicine Dean's Office, University of California San Francisco Health, Brin-Wojcicki Foundation, Robert Wood Johnson Foundation, National Institute on Drug Abuse, and Laura and John Arnold Foundation during the conduct of the study. No study authors have additional disclosures to report.

Author Contributions Drs. Mason, Epel, and Jacobs had full access to all of the data in the study, and take responsibility for the integrity of the data and the accuracy of the data analysis. *Concept and design:* Epel, Mason, Cohn, Jensen, Ishkanian, Wojcicki, Lustig, Schmidt. *Acquisition, analysis, or interpretation of data:* Mason, Epel, Jacobs, Leung, Cohn, Wojcicki, Lustig, Schmidt, Schleicher, Hartman. *Drafting of the manuscript:* Mason, Epel, Jacobs, Lustig, Cohn, Schleicher, Hartman, Schmidt.

Critical revision of the manuscript for important intellectual content: Mason, Lustig, Epel, Jacobs, Leung, Jensen, Ishkanian, Wojcicki, Schmidt. Statistical analysis: Mason, Epel, Jacobs. Obtained study funding: Epel, Jensen, Schmidt. *Administrative, technical, or material support:* Cohn, Schleicher, Hartman, Leung, Jensen, Ishkanian, Epel, Schmidt. *Staff supervision:* Epel, Cohn, Lustig, Schmidt.

Appendix 1.

Motivation	*M*(*SE*), low never	*M*(*SE*), high frequently	*p*
Craving strength (low vs. high)	29.37 (0.77)	30.55 (1.02)	.36
Stressed out (never vs. frequently)	29.21 (0.70)	31.02 (1.32)	.23
Taste enjoyment (never vs. frequently)	30.03 (1.75)	28.60 (0.73)	.45

Note. See Table 2 note.

Appendix 2.

M#	Predictor	B (*SE*)	*t*	*p*	95% CI [LB, UB]
1	Constant	0.87 (3.55)	0.24	.81	[−6.13, 7.86]
	SSB (baseline)	−0.80 (0.46)	−17.43	.00	[−0.89, −0.71]
	BI randomization	0.57 (4.50)	0.13	.90	[−8.31, 9.45]
	Craving strength	6.29 (1.10)	5.74	.00	[4.13, 8.46]
	BI randomization × craving strength	−4.54 (1.62)	−2.81	.01	[−7.72, −1.35]
2	Constant	26.34 (5.31)	4.96	.00	[15.87, 36.82]
	SSB (baseline)	−0.81 (0.05)	−15.79	.00	[−0.91, −0.71]
	BI randomization	−12.84 (7.02)	−1.83	.07	[−26.69, 1.00]
	Taste enjoyment	−5.82 (2.80)	−2.08	.04	[−11.33, −0.30]
	BI randomization × taste enjoyment	1.21 (4.06)	0.30	.77	[−6.79, 9.22]
3	Constant	27.63 (6.68)	4.13	.00	[14.45, 40.82]
	SSB (baseline)	−0.81 (0.05)	−15.60	.00	[−0.91, −0.71]
	BI randomization	−14.82 (9.43)	−1.57	.12	[−33.41, 3.78]
	Stressed out	−4.48 (2.54)	−1.76	.08	[−9.50, 0.54]
	BI randomization × stressed out	1.54 (3.78)	0.41	.68	[−5.92, 9.01]

Note. See Table 3 note.

Appendix 3.

M#	Predictor	*b* (*SE*)	*t*	*p*	95% CI [LB, UB]
1	Constant	1.95 (9.30)	0.21	.83	[−16.43, 20.32]
	Age	−0.21 (0.13	−0.16	.87	[−0.27, 0.23]
	SSB (baseline)	−0.85 (0.06)	−15.30	.00	[−0.96, −0.74]
	Biological sex (male)	1.02 (2.72)	0.37	.71	[−4.35, 6.38]
	Job category				
	Support clerk	1.30 (4.42)	0.30	.77	[−7.42, 10.03]
	Service maintenance	6.33 (4.39)	1.44	.15	[−2.35, 15.00]
	Medical	2.22 (5.76)	0.39	.70	[−9.17, 13.61]
	Academic	−5.72 (7.29)	−0.79	.43	[−20.13, 8.68]
	Other	3.38 (4.60)	0.74	.46	[−5.71, 12.47]
	BMI	−0.10 (0.21)	−0.50	.61	[−0.51, 0.30]
	BI randomization	0.70 (4.92)	0.14	.89	[−9.02, 10.43]
	Craving strength	6.62 (1.15)	5.77	.00	[4.35, 8.89]
	BI randomization × craving strength	−4.03 (1.86)	−2.17	.03	[−7.71, −0.36]
2	Constant	22.89 (11.01)	2.08	.04	[1.12, 44.65]
	Age	−0.01 (.15)	−0.06	.95	[−0.31, 0.29]
	SSB (baseline)	−0.82 (0.07)	−12.61	.00	[−0.95, −0.69]
	Biological sex (male)	−0.92 (3.12)	−0.29	.77	[−7.10, 5.26]
	Job category				
	Support clerk	1.24 (5.08)	0.25	.81	[−8.79, 11.28]
	Service maintenance	6.44 (5.19)	1.24	.22	[−3.83, 16.71]
	Medical	4.70 (6.64)	0.71	.48	[−8.43, 17.84]
	Academic	−2.67 (8.41)	−0.32	.75	[−19.29, 13.95]
	Other	2.46 (5.25)	0.47	.64	[−7.92, 12.85]
	BMI	−0.02 (0.23)	−0.09	.93	[−0.48, 0.44]
	BI randomization	−13.12 (8.09)	−1.62	.11	[−29.12, 2.88]
	Taste enjoyment	−4.64 (3.10)	−1.50	.14	[−10.78, 1.49]
	BI randomization × taste enjoyment	1.87 (4.72)	0.40	.69	[−7.47, 11.22]
3	Constant	25.25 (11.65)	2.17	.03	[2.21, 48.29]
	Age	0.02 (0.15)	0.10	.92	[−0.28, 0.31]
	SSB (baseline)	−0.82 (0.07)	−12.62	.00	[−0.95, −0.69]
	Biological sex (male)	−0.02 (3.12)	−0.01	.99	[−6.19, 6.14]
	Job category				
	Support clerk	2.03 (5.05)	0.40	.69	[−7.96, 12.01]
	Service maintenance	6.76 (5.15)	1.31	.19	[−3.43, 16.96]
	Medical	6.24 (6.53)	0.96	.34	[−6.67, 19.15]
	Academic	−0.18 (8.24)	−0.02	.98	[−16.47, 16.11]
	Other	3.51 (5.24)	0.67	.51	[−6.86, 13.88]
	BMI	−0.76 (0.23)	−0.33	.75	[−0.54, 0.39]
	BI randomization	−19.17 (10.43)	−1.84	.07	[−39.78, 1.44]
	Stress	−4.25 (2.66)	−1.59	.11	[−9.52, 1.03]
	BI randomization × stress	3.62 (4.16)	0.87	.39	[−4.60, 11.84]

Note. See Table 3 note. Pattern of results does not change after accounting for body mass index (BMI).

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