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Leveraging delay discounting for health: Can time delays influence food choice?

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Abstract

Delay discounting, the tendency to choose smaller immediate rewards over larger delayed rewards, is theorized to promote consumption of immediately rewarding but unhealthy foods at the expense of long-term weight maintenance and nutritional health. An untested implication of delay discounting models of decision-making is that selectively delaying access to less healthy foods may promote selection of healthier (immediately available) alternatives, even if they may be less desirable. The current study tested this hypothesis by measuring healthy versus regular vending machine snack purchasing before and during the implementation of a 25-second time delay on the delivery of regular snacks. Purchasing was also examined under a \$0.25 discount on healthy snacks, a \$0.25 tax on regular snacks, and the combination of both pricing interventions with the 25-second time delay. Across 32,019 vending sales from three separate vending locations, the 25-second time delay increased healthy snack purchasing from 40.1% to 42.5%, which was comparable to the impact of a \$0.25 discount (43.0%). Combining the delay and the discount had

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a roughly additive effect (46.0%). However, the strongest effects were seen under the \$0.25 tax on regular snacks (53.7%) and the combination of the delay and the tax (50.2%). Intervention effects varied substantially between vending locations. Importantly, time delays did not harm overall vending sales or revenue, which is relevant to the real-world feasibility of this intervention. More investigation is needed to better understand how the impact of time delays on food choice varies across populations, evaluate the effects of time delays on beverage vending choices, and extend this approach to food choices in contexts other than vending machines.

Keywords

Delay discounting; Pricing interventions; Behavioral economics; Vending machines; Food choice

INTRODUCTION

Obesity and poor diet quality are highly prevalent risk factors for morbidity and mortality from cardiovascular disease, diabetes, certain cancers, and other conditions [1–6]. Food choice and eating behavior are heavily driven by reward processing (i.e., the sensory experience of palatable food) [7, 8], and hyperpalatable foods saturate the modern environment [9]. For example, there are currently 3.5 million vending machines throughout the U.S. [10] – roughly one machine for every 70 adult inhabitants. Though U.S. adults derive less than 1% of daily energy from vending machines [11], vending snacks disproportionately contribute to poor diet quality. As of 2016, the 20 top-selling U.S. vending snacks were all candies, pastries, or full-fat chips [10].

The inability to resist palatable foods has been attributed to delay discounting, a tendency to prefer less valuable immediate rewards to more valuable but delayed alternatives [12–14]. Specifically, the subjective value of a reward, and therefore its influence on choice at the point of decision, declines at a hyperbolic rate in the interval before the reward becomes available [15]. Hyperbolic delay discounting accounts for the phenomenon of “preference reversals,” whereby individuals make short-sighted, impulsive decisions that conflict with his or her own long-term interests [16, 17]. In the context of obesity and diet quality, the prospect of immediate gratification from food *now* can supersede the competing long-term goals of maintaining a healthy weight and nutritional health, which are perpetually perceived as occurring in the future.

A growing literature supports linkages between individual differences in delay discounting rates and various dimensions of eating behavior [18]. Individuals who steeply discount delayed rewards and find food highly reinforcing have been found to consume more palatable food in both laboratory and real-world settings [19, 20]. Steep discounting has been associated with more frequent fast food consumption [21], and selection of more energy-dense items at away-from-home food sources [22]. Steep discounting rates have been associated with obesity in most studies, but with some notable exceptions [18, 23–26]. Given that both steep discounting and obesity are more prevalent in individuals with lower socioeconomic status [27, 28], delay discounting may represent an intermediate

neurocognitive process through which social and ecologic adversity contributes to disparities in diet quality, obesity, and other outcomes [29, 30].

Prior studies have largely focused on associations between *individual differences* in discounting rates and eating behaviors, and little work has sought to leverage the general principle of delay discounting for the purposes of dietary intervention. An interesting but untested implication of delay discounting models of decision making is that selectively applying time delays to less healthful foods may reduce their subjective value relative to healthier alternatives at the point of decision. Said differently, making healthier food options more immediately available may increase their relative value and induce a preference reversal towards a healthier option. The current study tested this hypothesis in the context of real-world vending machine snack choices. The proportion of vending sales from healthy versus regular snacks was measured during a baseline condition, and with brief time delays applied to the delivery of regular snacks. Additionally, healthy snack purchasing was assessed under two forms of differential pricing (a common intervention strategy [31]), and when differential pricing was combined with time delays. Given the potential for time delays to harm vending sales, and that financial considerations are major determinants of the real-world feasibility of this approach, changes in daily vending sales and revenue were monitored across all experimental conditions. The primary hypothesis was that time delays would increase the proportion of healthy snacks purchased relative to no intervention, without substantially harming vending sales or revenue. Our secondary aim was to explore the effects of time delays in combination with both price discounts and taxes.

METHODS

Overview

Prior to the main trial, a small dose-finding pilot study was conducted to identify the optimum delay interval that maximized healthy purchasing without decreasing vending sales. Given its focus, the dose-finding pilot study utilized a convenience sample and occurred at a single vending location. After the optimum time delay interval was identified, a larger trial subsequently tested the impact of the delay on snack choice, both alone and in combination with two differential pricing interventions. The main trial occurred in three real-world vending locations at an urban medical center campus. As the project examined the effects of an environmental manipulation on population-level vending machine purchase data, no individual-level intervention or data collection with research subjects took place. The project was categorized as exempt from review by the Institutional Review Board of Rush University Medical Center. Study procedures were conducted in accordance with the Declaration of Helsinki. The trial was registered in advance of data collection through clinicaltrials.gov (NCT02359916).

Dose-finding pilot study

The dose-finding pilot study involved a convenience sample of 170 adults. Potential subjects were approached by research staff and offered a coupon for a free vending machine snack (the coupon functioned as currency when inserted into the vending machine). Subjects were informed that regular snacks vend after a specific time delay, and that healthy snacks vend

immediately. The 11 time delays examined ranged from 0 to 30 seconds in 3-second intervals (e.g., 0, 3, 6, 9 ... 30 seconds). Fifty subjects participated under no time delay (0 seconds) to obtain a reliable estimate of baseline purchasing, and twelve subjects participated at each of the non-zero time delays. Subjects were invited to purchase a snack of their choice using their coupon, but were also given the opportunity to exchange their vending coupon for \$1.00 USD (equivalent to the price of one snack) if they were unwilling to endure the delay. The purpose of offering this option was to determine whether exchanges occurred more frequently at increasing time delay intervals, which would suggest that extended time delays might harm sales under more naturalistic conditions. Research staff recorded the number of healthy and regular snacks chosen at each delay interval, and documented all instances when a subject exchanged their coupon for cash. Our *a priori* goal was to select the delay interval that produced the greatest increase in healthy snack purchasing without exceeding a 10% exchange rate. As shown in Figure 1, the proportion of healthy snacks chosen increased with longer time delay intervals, reaching a plateau at about 65–70% healthy snacks for delay intervals of 15 seconds and beyond. Only 5 subjects exchanged their coupons for cash at the 3-second ($n=2$), 6-second ($n=1$), and 27-second ($n=2$) delay intervals. Based on these data, a delay interval of 25 seconds was used in the main trial described below.

Main trial design

The main trial utilized a repeated measures, experimental design in which several vending machine interventions were implemented sequentially in each of three vending locations between June 2015 and August 2016. All three vending locations were located on the campus of a large academic medical center. One vending location was in a public setting, accessible to both medical center staff and visitors. The second location was in a staff breakroom that was accessible primarily to “blue collar” workers in the medical center, such as supply receiving and inventory management, security personnel, and hospital food service workers. The third location was located in an office building accessible primarily to “white collar” workers. A small canteen that primarily sold sandwiches, salads, and soups was located on the same building floor as the vending machine in the office building. There were no other vending machines or other food sources in the vicinity at any of the sites. The order of six distinct experimental conditions could not be counterbalanced with only three vending locations. Therefore, the same sequence of conditions was implemented in all three vending sites (Figure 2). The condition involving time delays immediately followed the first baseline period to minimize potential carryover effects from other conditions in this high-priority comparison. Each condition ran for approximately 4 weeks. An *a priori* power analysis conducted for the main trial indicated that sales of about 700 total purchases in each condition would yield .83 power to detect an increase in healthy snack purchasing rates as small as 10% at $\alpha=0.05$.

In the course of data collection, the team learned that the machine in the public location was so heavily utilized that it was often completely depleted of snacks by the end of the day, and usually required restocking twice daily. Given the frequency with which this occurred, the proportion of healthy and regular snacks purchased at this location was heavily influenced by numbers of each snack stocked in the machine rather than by any intervention. For this

reason, the team decided to terminate data collection early at the public location and proceed with data collection in the other locations. Data from the public location are included in the main analyses, but sensitivity analyses excluding these data were also performed.

Implementation of time delays

All three vending locations examined in this study were equipped with the same model vending machine (model 167, Crane Merchandising Systems, Williston, SC, USA), which stocked 34 snacks (17 healthy, 17 regular) in 6 rows. The machines accepted cash or coins only; credit/debit cards were not accepted. For reasons explained below, regular snacks were stocked in the top three rows, and healthy snacks were stocked in the bottom three rows. Snacks were always stocked in the same locations within the machine throughout the study, and the locations were mapped to a visual layout that is referred to as a “planagram” in the vending industry. Graphics and color-coding schemes on the machine clearly distinguished between the three rows of healthy snacks (color-coded green, labeled as “Healthy snacks”), and the three rows of regular snacks (color-coded red, labeled “Regular snacks”). Additionally, the nutritional criteria used to define healthy vs. regular snacks could be accessed through a 5.7-inch touchscreen display embedded within the vending machine door (MIND Screen, Vendors Exchange International, Cleveland, OH).

The 25-second time delay intervention was implemented by retrofitting each vending machine with a removable device designed and constructed by the research team (patent PCT/US2015/046056, WO/2016/028986). The device includes a thin, horizontal platform that spans the width of the vending machine, and an array of infrared light emitters and sensors that project across the length of the platform. The platform can be installed at any height within the machine with magnet-held brackets. When any snack located above the platform is purchased, it is intercepted by the platform before it falls to the dispensing drawer at the bottom of the machine. The snack interrupts the infrared light beams, and this interruption is detected by the light sensors. Interruption of the beam by a snack triggers a 25-second countdown, which is displayed on a countdown timer positioned in the vending machine door. When the countdown expires, the platform rotates and releases the snack into the dispensing drawer below. As the device can only delay the delivery of snacks that fall from a higher location in the machine, regular snacks were placed in the top three rows of the machine, and the platform was positioned just below these three rows. When the time delay intervention was active, the machine was labeled with large graphics on the vending door glass that included a large stopwatch set to 25-seconds, and labels indicating that “Regular snacks vend after a 25-second delay” and “Healthy snacks vend immediately.” The intervention was also noted on the LED touchscreen display (“You may have to wait for your snack /Regular snacks vend after a 25-second delay/ Healthy snacks vend immediately”). When the time delays were not active, the relevant graphics, the messaging on the LED touchscreen, and the device itself were removed from the machine. However, the labelling distinguishing regular from healthy snacks was present in all conditions.

Vending interventions

In the *No Intervention* (control) condition, regular and healthy snacks were priced at \$1.00, and all snacks vended immediately. This condition was implemented twice in each location,

at the beginning and end of the data collection period. In the *Time Delay Only* condition, regular and healthy snacks were priced at \$1.00, and regular snacks vended after a 25-second delay (healthy snacks vended immediately). In the *Discount Only* condition, regular snacks were priced at \$1.00 and healthy snacks were priced at \$0.75. All snacks vended immediately. In the *Tax Only* condition, regular snacks were priced at \$1.25 and healthy snacks were priced at \$1.00, with all snacks vending immediately. The *Delay + Discount* and *Delay + Tax* conditions used the same differential pricing interventions as the *Discount Only* and *Tax Only* conditions (respectively), but also applied a 25-second time delay to regular snack purchases. It is noteworthy that the price differential (\$0.25) between healthy and regular snacks was identical in the *Discount Only* and *Tax Only* conditions, but the *Tax Only* conditions required users to have at least two units of currency (e.g., one dollar bill and a quarter, two dollar bills, etc.).

Criteria for healthy and regular snacks

Healthy snacks met at least five of the seven nutritional criteria listed in Table 1. Regular snacks met four or fewer of these criteria. Table 1 also includes the mean portion sizes (weight) and nutrient content for healthy and regular snacks. Criteria for healthy snacks, and the specific snacks offered, were determined by the food management service at the study site and were not within the control of the investigators. The specific snacks that were sold are listed in the Appendix.

Intervention fidelity

Implementing the pricing interventions required strong cooperation with the vending machine operators, who were responsible for keeping the machines stocked, adjusting snack prices, and collecting and reporting sales data. Vending machine operators stocked the machines based on the “planagram” set by the research team, which depicted the location of each snack within the machine. The vending snacks and their locations within the machine remained constant throughout the entire project. Research staff checked machines on most weekdays (as reported below) to verify that snacks were adequately stocked, placed in the appropriate location, and correctly priced. Deviations from the planagram were documented.

Data collection and processing

Vending machine operators, who were not members of the research team, downloaded vending sales data using a handheld electronic device that connected to the vending machine’s circuit board. Data downloads occurred every time cash was collected from the machines, which was typically once daily. Each data download summarized the quantity of each snack sold since the previous download, as well as the price at which it was sold. Data downloads that included sales under two different experimental conditions were excluded from analysis as it was not possible to determine which specific snack purchases were made under each condition (individual vending transactions were not time-stamped).

The research team received daily sales data from the vending machine operator on a continuous basis throughout the study. Sales data were imported into a database, and merged with the intervention fidelity data on stocking, placement, and pricing for each item (described above). The total numbers of healthy snacks, regular snacks, and total snacks

sold, as well as total vending revenue, were calculated for each condition. Average daily sales (number of snacks purchased per day) and average daily vending revenue (in U.S. dollars per day) in each condition were calculated.

Statistical Analyses

Intervention fidelity data were calculated as the total numbers of stocking errors, out-of-stock items, and pricing errors documented throughout the study. To determine the need to account for temporal trends in snack purchasing over time, total snack sales were plotted against calendar date and the plot was visually inspected for periods characterized by potentially meaningful increases or decreases in sales. Based on the observed temporal pattern of vending sales, preliminary analyses were conducted to test the linear trend in purchasing rates over time, the difference in purchasing rates on weekends vs. weekdays, and the difference in purchasing rates during the winter holiday season (December 13 through January 5) vs. the rest of the calendar year.

The primary analyses utilized generalized estimating equations (GEE), which is an extension of the general linear model that is suitable for repeated (i.e., clustered) categorical or continuous outcomes. Such an approach was appropriate for the present analyses, which involved both categorical (healthy vs. unhealthy snack purchases) and continuous (daily snack sales and revenue) data clustered within sites and conditions. Furthermore, GEE can incorporate random intercepts, which enabled modeling of different baseline values in each vending location. Models examining the proportion of total snack purchases from healthy items included terms for the effects of condition (reference: *No Intervention*) and vending location (public, blue collar, white collar). Planned contrasts compared the proportion of purchases from healthy items under each of the five experimental conditions with that under no intervention. The same modeling strategy was used to examine the effects of condition on repeated observations of total vending sales and total daily vending revenue. The main analyses included all three vending locations. However, given the frequent depletion and early termination of data collection in the public vending location, a sensitivity analysis was performed using data only from the blue collar and white collar vending locations only. The location by condition interaction term was tested to determine whether intervention effects differed between the “blue collar” and “white collar” locations. Subsequently, contrasts compared the two locations on the magnitude of change in healthy snack purchasing under each experimental condition relative to *No Intervention*. The public location was not included in these comparisons due to being terminated prematurely.

RESULTS

Intervention fidelity

Across the three vending locations, data were collected for a total of 682 observation days. Research staff performed at least one intervention fidelity check on 414 of these days, which corresponds to 61% of total days and 85% of weekdays. Stocking errors were identified on 202 days. Though this represents almost half (49%) of the fidelity assessments, virtually all of the stocking errors consisted of the same two adjacent items being switched persistently throughout the entire duration of the study (e.g., two adjacent varieties of chips were always

stocked in the other item's location). Importantly, there were no instances in which a healthy snack was incorrectly stocked in the location of a regular snack, or vice versa. Therefore, stocking errors were simply corrected by realigning sales data to the correct snack within the database. Out-of-stock items were documented on 68% of fidelity assessment days, with an average of 3.2 out-of-stock items noted at each assessment. Out-of-stock items were distributed evenly between the healthy (53%) and regular (47%) snacks. No pricing errors were observed during the study.

Time-related trends

Several time-related trends in total vending sales were examined. No overall trend in vending sales was observed across the duration of the study (estimate=0.17, SE=0.15, $p=.24$). Vending sales were 23.6% lower on weekends compared to weekdays (estimate=-15.07, SE=0.438, $p<.001$), and 38.2% lower between December 13 and January 5 compared with the rest of the year (estimate=-23.12, SE=9.01, $p<.0001$). The primary analyses reported herein adjusted for the two statistically significant time-related trends, though doing so did not alter the findings.

Effects of condition on healthy vending sales

A total of 32,019 vending sales were included in the primary analysis examining the proportion of total snack purchases from healthy items in each condition. Comparisons between conditions on healthy snack purchasing are depicted in Figure 3, panel A. Compared to the observed value of 40.1% under *No Intervention*, the proportion of total sales from healthy snacks increased to 42.5% under *Time Delay Only*, 43.0% under *Discount Only*, 46.0% under *Delay + Discount*, 53.7% under *Tax Only*, and 50.2% under *Delay + Tax* (Table 2). The pattern and significance of findings was essentially the same in the sensitivity analysis that excluded data from the public vending location, with the proportions of sales from healthy snacks increasing from 42.0% (95% C.I. 40.6–43.4%) under *No Intervention*, to 45.1% (95% C.I. 43.2–46.9%) under *Time Delay Only*, 44.2% (95% C.I. 42.3–46.2%) under *Discount Only*, 47.9% (95% C.I. 45.7–50.2%) under *Delay + Discount*, 55.6% (95% C.I. 53.8–57.4%) under *Tax Only*, and 52.1% (95% C.I. 50.2–54.1%) under *Delay + Tax*.

Effects of condition on vending sales and revenue

Figure 3 (panels B and C) depicts total daily vending sales and total daily vending revenue across study conditions. The number of snacks purchased per day did not significantly differ from *No Intervention* in any other condition (Table 2). Similarly, average daily vending revenue under *No Intervention* was not significantly different from revenue within any other condition (Table 2).

Comparisons between “blue collar” and “white collar” locations

The proportion of sales from healthy snacks under *No Intervention* was significantly higher in the “white collar” location (47.3%, 95% C.I. 45.7–49.0%) than the “blue collar” location (36.6%, 95% C.I. 34.4–38.8%). A significant interaction between condition and location was observed when modeling the proportion of healthy snacks purchased ($F_{(6,416)}=31.50$, $p<.$

0001). The interaction is depicted in Figure 4, which displays the degree to which the proportion of healthy snack sales increased in each condition compared to *No Intervention* (i.e., relative percentages) separately by location. Contrasts probing the interaction indicated that the *Delay + Discount* condition produced a larger increase from *No Intervention* in healthy snack purchasing in the “blue collar” location compared to the “white collar” location (estimate=0.24, $t=2.19$, $p=.03$). The pattern of differences was similar for the *Tax Only* (estimate=0.17, $t=1.75$, $p=.08$) and *Delay + Tax* (estimate=0.16, $t=1.52$, $p=.13$) conditions, but these contrasts were not statistically significant. Conversely, the increases in health snack purchasing produced by the *Time Delay Only* (estimate=-0.13, $t=-1.34$, $p=.18$) and *Discount Only* (estimate=-0.07, $t=-0.75$, $p=.45$) interventions did not significantly differ by location. The “blue collar” and “white collar” locations did not differ in average daily vending sales ($t=-1.54$, $p=.12$) or average daily vending revenue ($t=-1.38$, $p=.17$).

DISCUSSION

This study experimentally tested the effect of brief time delays on healthful vending machine snack choices, both alone and in combination with two differential pricing interventions. All interventions increased the proportion of healthy snacks relative to no intervention, though to different extents. Applying a 25-second time delay to sales of regular snacks produced a small but meaningful increase in the proportion of healthy snacks sold. This effect was comparable to the improvement seen with a 25-cent discount on healthy snacks. The present findings are consistent with delay discounting models of decision making in which choice is influenced by whether an alternative is available immediately or following a delay. The present findings are also consistent with prior observational studies that report healthier meal and grocery selections with longer delivery lead times [32–34]. The present study extended these findings to a vending context where food options are truly available immediately (within seconds rather than hours or days), and demonstrates that this principle can be leveraged as an intervention to promote healthful food choices in a field setting.

As reported in prior studies [35–38], differential pricing increased purchasing rates for healthy snacks. The extent to which price manipulations influence consumption (the price elasticity of demand; [39]) varies according to both the type of food being examined [40, 41] and the alternative foods available for consumption (i.e., cross-price elasticity; [42]). In the present study, price manipulations were designed to shift choices from the set of regular snacks to the set of healthy snacks. Though the two differential pricing interventions examined were equivalent in terms of their magnitude (\$0.25), the *Tax Only* and *Delay + Tax* conditions had the strongest effects on healthy snack sales. This pattern contrasts with a recent meta-analysis of pricing interventions which found that price decreases generally have stronger effects on food choice than price increases, [43]. One explanation for this discrepancy may be that the 25-cent tax translated to prices of \$1.25 for regular snacks, which required the consumer to have at least two units of currency (e.g., one dollar bill and one quarter). The need for two units of currency may represent a small barrier to purchasing, and the prospect of being left with loose change following the transaction may be aversive to some individuals. To better understand the differential impact of 25-cent discounts versus taxes, it would be necessary to implement both differential pricing interventions in a way that does not necessitate a different number of currency units. This could be done by pricing

both discounts and taxes within the same whole dollar (i.e., a \$0.10 discount or a \$0.10 tax applied to a base price of \$0.80), or by comparing discounts and taxes in newer vending machines that accept credit/debit cards as payment. Combining a discount with a 25-second time delay had an additive impact on healthy snack sales, suggesting the potential value of implementing both interventions simultaneously in real-world settings. However, combining a time delay with a tax did not improve healthy snack purchasing rates beyond that seen under *Tax Only*, which may be attributable to a ceiling effect.

Meaningful differences in healthy snack purchasing were observed between the “blue collar” and “white collar” vending locations. Purchasing of healthy snacks was substantially higher in the “white collar” location than the “blue collar” location under baseline conditions and during all interventions. Additionally, the combination of a delay and price discount produced a larger improvement in healthy snack purchasing in the “blue collar” location than the “white collar” location. Similar (but non-significant) trends were seen for the *Tax Only* and *Delay + Tax* conditions. The time delay only and discount only conditions, which might be considered weaker interventions, produced similar effects in both locations. This pattern could suggest that more intensive interventions, or a combination of interventions, may be required to impact choices among populations who are less inclined towards healthier options to begin with. As no individual level data were collected from consumers, it is not possible to characterize the population at each site beyond their baseline level of healthy snack purchasing under no intervention. Socioeconomic status, cultural factors, and neurobehavioral traits such as food reward sensitivity and executive function have all been related to both eating behaviors [24, 44–46] and responsiveness to dietary interventions [47–49], and it is intriguing to consider whether such factors might account for the observed differences between sites in the present study.

Time delays could have a beneficial effect on vending snack choices, but would not be widely disseminated if they harm vending revenue. None of the vending interventions implemented in this study had an appreciable impact on overall vending sales volume, or on daily vending revenue. As would be expected, average daily vending revenue was slightly lower in the two conditions involving price discounts compared to the other conditions, but these differences were not statistically significant. To the extent to which price discounts may harm overall vending revenue, time delays may represent a more financially feasible strategy to promote healthy purchasing. Ultimately, successfully implementing time delay interventions in real-world vending locations will require partnership with a vending machine manufacturer that is willing to develop and market machines with time delay mechanisms. Support from the vending machine operators who place and maintain the machines is also crucial. There is high demand for healthy vending programs among businesses, schools, and other entities that host vending locations [10], and consumer interest in time delays as an alternative to restriction-based and differential pricing interventions deserves investigation.

The current study provides initial evidence that time delays can influence snack choice, but the potential public health significance of this approach will ultimately depend on several factors. Greater improvements in dietary intake would be expected where promoted and time-delayed snacks differ substantially in their nutritional profiles, and in settings where

vending machine purchases represent a larger share of overall diet (e.g., among nightshift workers). It has been estimated that reducing average daily energy intake by less than 20 kcal/d would halt the progression of the obesity epidemic, and a reduction of about 220 kcal/d would eventually reverse the prevalence of obesity to pre-epidemic levels [50–52]. It could be reasonably presumed that widely disseminated vending machine interventions could meaningfully contribute to these relatively small changes in intake.

Strengths and limitations

This study had several noteworthy strengths and limitations. The interventions examined were implemented with high fidelity, which was assessed frequently throughout the project. The use of existing real-world vending locations increases the external validity of the study, and allowed for a comparison of intervention effects in two distinct settings. However, both vending locations were located at the same institution; therefore, testing in more diverse settings is warranted. Further, the selection of healthy and regular snacks was made by the study site, and intervention effects may differ when the regular and healthy snacks are more or less similar in terms of their nutritional profile, palatability, portion size, or other factors. It would be particularly interesting to test whether time delays may promote purchasing of low-calorie beverages relative to higher-calorie beverages, as beverage sales represent the largest share of vending sales in the U.S [10] and caloric beverage consumption is a major public health concern [53, 54]. The study was limited in that it tested a single delay interval of 25 seconds. Though the potential efficacy and feasibility of this delay interval was supported by a dose-finding pilot study, the optimal balance between promoting healthy snack purchasing and harming vending sales would be expected to vary by setting and the population of consumers targeted. For example, shorter delays may be more effective with children, who tend to exhibit steeper delay discounting rates [55] and would, in theory, be more likely to experience a preference reversal at shorter delay intervals.

Given the nature of vending sales data, it was possible to statistically model the probability that a healthy snack would be purchased in each condition utilizing data from over 32,000 vending sales. Conversely, total vending sales and revenue were analyzed as a rate, based on average daily totals over 682 observation days. Thus, the analyses for vending sales and revenue was based on fewer observations, and were likely underpowered to detect small-magnitude effects of condition.

An additional limitation pertains to the device used to implement the time delays in this study, which was designed to “catch” and temporarily hold snacks after they had been purchased. This approach was functional, but required that the regular snacks be placed above the platform within the machine. The location of snacks was constant across conditions, but the fact that regular snacks were at eye-level (and color-coded and labelled as healthy vs. regular) may have influenced purchasing rates across all conditions. Additionally, the fact that the time delay device was not integrated with the vending machines control board precluded a mechanism that would allow the consumer to change their snack selection during the time delay (i.e., during the delivery countdown). Such a mechanism could enhance the degree to which time delays ultimately lead to the selection of a healthier option.

Conclusions

Applying a brief time delay to the delivery of less healthy snacks has a small but reliable impact on healthy snack purchasing rates, with no significant harm to vending sales or revenue. Additional studies, conducted in collaboration with vending industry partners, are needed to establish the effectiveness and feasibility of this novel approach in other contexts.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Appendix. Healthy and regular snacks sold in the study vending machines

Regular snacks	Healthy snacks
Fritos®, original, 2 oz (Frito-Lay, Purchase, NY)	Lay's® Kettle Cooked, Jalapeño Cheddar, 1.4 oz, (Frito-Lay, Purchase, NY)
Doritos®, original, 1.77 oz (Frito-Lay, Purchase, NY)	Lay's® Kettle Cooked, Aged Cheddar and Black Pepper Potato Chips, 1.4 oz, (Frito-Lay, Purchase, NY)
Cheetos®, original, 2 oz (Frito-Lay, Purchase, NY)	Quaker® Popcorn Cakes, Caramel, 0.91 oz, (General Mills, Chicago, IL)
Fritos®, Chili Cheese, 2 oz (Frito-Lay, Purchase, NY)	Welch's® Fruit Snacks, Berries and Cherries, 2.25 oz, (Welch's, Concord, Massachusetts)
Lay's® Classic Potato Chips, 1.5 oz (Frito-Lay, Purchase, NY)	Welch's® Fruit Snacks, Concord Grape, 2.25 oz, (Welch's, Concord, Massachusetts)
Cheetos®, Flamin' Hot, 2 oz (Frito-Lay, Purchase, NY)	Lay's® Oven Baked Potato Chips, Original, 1.13 oz (Frito-Lay, Purchase, NY)
Cheetos®, Cheddar Jalapeño, 2 oz (Frito-Lay, Purchase, NY)	Lay's® Oven Baked Potato Chips, Barbecue, 1.13 oz (Frito-Lay, Purchase, NY)
Ruffles®, Cheddar and Sour Cream, 1.5 oz (Frito-Lay, Purchase, NY)	Lay's® Oven Baked Potato Chips, Sour Cream and Onion, 1.13 oz, (Frito-Lay, Purchase, NY)
Three Musketeers Bar®, 2.13 oz (Mars, Chicago, IL)	Smartfood® Popcorn, White Cheddar, 1 oz, (Frito-Lay, Purchase, NY)
Twix®, 1.79 oz (Mars, Chicago, IL)	Snyder's of Hanover® Pretzels, 1.58 oz, (Snyder's Lance, Bedford Park, IL)
Snickers®, 1.86 oz, (Mars, Chicago, IL)	Wheat Thins Toasted Chips, Vegetable, 1.75 oz (Kraft Nabisco, East Hanover, NJ)
M&Ms®, Milk Chocolate, 1.69 oz, (Mars, Chicago, IL)	Ruffles® Oven Baked, Cheddar and Sour Cream, 1.13 oz, (Frito-Lay, Purchase, NY)
Garden of Eatin'™ Snack Mix, 1.75 oz (General Mills, Chicago, IL)	Nature Valley™ Granola Bars, Oats n' Honey, 1.49 oz (General Mills, Chicago, IL)
Big Texas Cinnamon Roll®, 4 oz (Aryzta Bakeries, Chicago, IL)	M&M's®, Peanut, 1.74 oz (Mars, Chicago, IL)
Pop Tarts®, Strawberry Frosted, 3.52 oz (Kellogg Co, Chicago, IL)	Munch Peanut Bar®, 1.42 oz (Mars, Chicago, IL)
Milky Way® Bites, 2.83 oz (Mars, Chicago, IL)	Special K® Pastry Crisps, Blueberry, 0.87 oz (Kellogg Co, Chicago, IL)

Figure 1.

Data from dose-finding pilot study (N=170) of delay intervals. The line represents the proportion of healthy snacks chosen when increasingly long time delays were applied to regular snacks. Data are depicted with 4-neighbor smoothing. The number of instances where subjects exchanged their coupons for cash are shown just below the trendline. A 25-second delay interval was ultimately selected for the main trial.

A Equal pricing No delay	B 25¢ discount No delay	C Equal pricing 25-s delay	D 25¢ discount 25-s delay	E 25¢ tax No delay	F 25¢ tax 25-s delay	G Equal pricing No delay
~4 weeks	~4 weeks	~4 weeks	~4 weeks	~4 weeks	~4 weeks	~4 weeks

Figure 2.

Sequence of experimental conditions in the main trial. Conditions were implemented in the same order in all three vending locations. The duration of each condition was approximately 4 weeks.

Figure 3.

Study outcomes by condition (means and standard error bars). Panel A depicts the proportion of total sales from healthy snacks as absolute percentages, with all healthy snack sales being significantly higher than under *No Intervention* in all other conditions. Panel B illustrates the lack of statistically significant differences in daily vending sales across conditions, whereas Panel C shows that daily vending revenue did not significantly vary by condition. Asterisks indicate significant difference from *No Intervention* at $p < .001$.

Figure 4.

Changes in the proportion of sales from healthy snacks in the “blue collar” and “white collar” locations, expressed as a relative percentage of baseline sales (not an absolute percentage) under *No Intervention* in the respective location. Asterisk indicates a significant difference between locations at $p < .05$.

Table 1

Nutrition criteria and mean nutrient content for the 17 healthy and 17 regular snacks. Snacks had to meet at least five of the nutrition criteria to be categorized as healthy.

Component	Criteria for healthy snack (per serving)	Healthy (M)	Regular (M)
Weight (g)	--	42.2	57.1
Energy (kcal)	<250 kcal	183	277
% energy from fat (%)	35% energy from fat, or most fat originating from natural sources (e.g., nuts)	27	46
Sodium (mg)	350 mg	186	311
<i>Trans</i> - fat (g)	No <i>trans</i> - fat	0.04	0.31
% energy from saturated fat (%)	5% of daily value, or most saturated fat originating from natural sources (e.g., nuts)	5	12
Fiber (g)	1 g of dietary fiber	2	2
Added sugar (g)	10 g of added sugar	9	13

Table 2

Mean values and results of statistical comparisons between each intervention condition and the *No Intervention* control condition.

Condition	Mean (95% C.I.)	Model estimate of difference from <i>No Intervention</i>	SE	t	p
Percentage healthy choices (%)					
<i>No Intervention</i>	40.1 (39.1, 41.2)	--	--	--	--
<i>Delay Only</i>	42.5 (41.3, 43.8)	0.10	0.03	3.25	0.001
<i>Discount Only</i>	43.0 (41.7, 44.4)	0.12	0.03	3.50	<0.001
<i>Delay + Discount</i>	46.0 (43.7, 48.3)	0.24	0.05	4.65	<0.0001
<i>Tax Only</i>	53.7 (51.8, 55.6)	0.55	0.04	12.21	<0.00001
<i>Delay + Tax</i>	50.2 (48.2, 52.2)	0.41	0.05	8.97	<0.00001
Daily vending sales (items/day)					
<i>No Intervention</i>	65.1 (59.2, 71.0)	--	--	--	--
<i>Delay Only</i>	65.8 (58.6, 73.1)	0.02	4.73	0.00	1.00
<i>Discount Only</i>	69.0 (60.7, 77.3)	3.35	5.10	0.66	0.51
<i>Delay + Discount</i>	61.2 (50.2, 72.2)	-4.44	6.35	-0.70	0.48
<i>Tax Only</i>	62.7 (53.5, 71.9)	-3.16	5.57	-0.57	0.57
<i>Delay + Tax</i>	65.4 (55.3, 75.5)	0.37	5.88	0.06	0.95
Daily vending revenue (\$/day)					
<i>No Intervention</i>	65.03 (58.97, 71.09)	--	--	--	--
<i>Delay Only</i>	65.94 (58.49, 73.39)	0.20	4.87	0.04	0.97
<i>Discount Only</i>	61.62 (53.09, 70.16)	-3.93	5.24	-0.75	0.45
<i>Delay + Discount</i>	55.94 (44.64, 67.24)	-9.61	6.53	-1.47	0.14
<i>Tax Only</i>	67.02 (57.53, 76.50)	1.24	5.73	0.22	0.83
<i>Delay + Tax</i>	70.34 (59.98, 80.70)	5.39	6.05	0.89	0.37