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Nudge to nobesity I: Minor changes in accessibility decrease food intake

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Abstract

Very small but cumulated decreases in food intake may be sufficient to erase obesity over a period of years. We examine the effect of slight changes in the accessibility of different foods in a pay-by-weight-of-food salad bar in a cafeteria serving adults for the lunch period. Making a food slightly more difficult to reach (by varying its proximity by about 10 inches) or changing the serving utensil (spoon or tongs) modestly but reliably reduces intake, in the range of 8–16%. Given this effect, it is possible that making calorie-dense foods less accessible and low-calorie foods more accessible over an extended period of time would result in significant weight loss.

Keywords: obesity, environment, behavior, choice architecture, nudge.

1 Introduction

Obesity is detrimental to health, and its prevalence has been growing steadily in the United States (and elsewhere) over recent decades. The National Health and Nutrition Examination Surveys (NHANES) estimate that the percentage of obese adults between the ages of 20 and 74 in America increased from 14.5 in 1974 to 33.8 in 2008 (Ogden & Carroll, 2010). Obesity is the second-leading cause of preventable deaths and increases risk of coronary heart disease, type II diabetes, and other serious medical conditions (National Institutes of Health, 1998). Although there is no doubt that obesity represents a serious health hazard, the framing of the problem as an "obesity epidemic" is misleading. Obesity does not have two of the critical properties of epidemics: (1) it is not contagious, and (2) its growth over time (years or decades) is not rapid and in an "S" shaped curve, but instead is very slow and steady.

The most common medical treatment for obesity is dieting. Yet most studies assessing this treatment find that it is ineffective. Even when dieters lose weight, these losses are rarely maintained (Mann et al., 2007; Garner & Wooley, 1991). One review even concludes that it is "only the rate of weight regain, not the fact of weight regain, that is in question" (Garner & Wooley, 1991, p. 740). According to Gallup polls, the percentage of Americans "seriously trying to lose weight" increased between 2003 and 2009, but Americans got heavier nevertheless (Jones, 2009).

A promising alternative approach to the obesity problem is not to focus on (or blame) the obese individual, but rather to focus on the environment as a principal and "treatable" cause. In recent years, a group of researchers have independently advocated a focus on the environment to control the national waistline. Originally proposed by Hill and Peters (1998), the approach has been endorsed, in one form or another, by Brownell (2002), Levitsky (2005), Rolls (2003), Rozin et al., (2003), Wansink (2004), and Young and Nestle (2002).

Estimates of the increase in body weight per year of Americans have been computed, and they vary depending on the time period measured and racial and age properties of the sample. Based on the NHANES and CARDIA data bases, annual weight gain estimates in American adults vary from 0.9 pounds (0.4 kg) to 2.5 pounds (1.1 kg) per year (Hill et al., 2003; Lewis et al., 2000; Levitsky and Pacanowski, 2011; and our own calculations). The creeping increase in obesity could be halted (or, in retrospect, could have been prevented) by a very modest reduction in calories in the range of 10 to 100 kilocalories/day, depending on many factors including assumptions about the efficiency of extracting energy from ingested foods (Hill et al., 2003; Levitsky & Pacanowski, 2011). Thus, a reduction in food intake starting twenty years ago of 1 to 8 apples per week, or 1 to 5 12 oz cokes per week, *all else equal*, would have completely eliminated the growth in obesity in the United States.

The environmental alternative, in its most common and probably most practical form, involves interventions that have modest but cumulative effects on food intake, corre-

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sponding to the modest annual gains in weight. A number of environmental interventions have been shown to decrease food intake in a meal. The best-documented environmental influence is portion size. Experiments in both laboratory and real world settings have established that increasing portion size increases consumption (e.g., Rolls, Morris, & Roe, 2002; Diliberti et al., 2004; Levitsky & Pacanowski, in press). Portion size has also been linked to BMI differences in field studies. The French—who consume more total fat and have slimmer figures than their American counterparts—have systematically and substantially smaller portion sizes in restaurants, food purchased in individual portion sizes, and cookbooks (Rozin et al., 2003). The slimmer status of the French strongly suggests that they eat fewer calories than Americans, probably in part because they consume smaller portion sizes.

The focus of the present studies is not on portion size, but on the influence of accessibility (meaning the ease with which a food item can be accessed) on food choice and intake. A number of existing studies implicate accessibility as a determinant of consumption. Most of these operationalize ease of access in terms of proximity (i.e., spatial location), which translates into effort. Early work manipulating effort was motivated by Schachter's (1971) theory of obesity, which predicted that obese individuals would reduce intake more than normal weight individuals as effort to obtain food increased. In general, the manipulations used in these studies involved substantial differences in effort. Nisbett (1968) showed that obese individuals ate fewer sandwiches if they had to walk to a refrigerator to get them while normals were unaffected. Similarly, Schachter and Friedman (1974) showed that obese individuals consumed less of shelled than unshelled almonds, but there was no effect for normals. Schachter, Friedman, and Handler (1974) showed that, of the Caucasian patrons eating at a Chinese restaurant, obese patrons were less likely to use chopsticks (which, presumably, require more effort) than normal weight patrons. Another study supporting the Schachter view was a demonstration that obese individuals eat fewer cashews when they are individually wrapped and normals do not, but the study also found no reduction in either group for wrapped versus unwrapped chocolates (Singh & Sikes, 1974). Other studies testing the Schachter hypothesis show no differences in environmental influence on obese versus normal subjects. Levitz (1976) and Meyers, Stunkard, and Coll (1980) showed a reduction in low-calorie dessert consumption when they were placed at the back (in a four row deep dessert display) as opposed to the front, in a cafeteria setting. Neither study reported a difference between obese and normal weight persons. Levitz (1976) also reported that when the lid was on an ice cream cooler in a cafeteria setting, it reduced ice cream intake substantially in both obese and normal weight individuals.

Studies done outside the Schachter framework also show effects of effort/accessibility. Meiselman et al. (1994) reported large decreases in intake of potato chips and candy in a cafeteria setting, when they were made quite inaccessible, by locating them some distance from the main serving line. Engell et al. (1996) found that individuals drink more water while eating if the water pitcher is on the table versus 20 or 40 feet away. More recently, Wansink, Painter, and Lee (2006) demonstrated that secretaries consume more candy when the bowl is on their desk as opposed to at another location in the room.

Access can potentially be operationalized in subtler ways; examples include changing proximity by a matter of inches (i.e., changing the ease with which a food can be reached and how much and in what direction one must stretch to reach it), and changing ease of transfer (i.e., how easy it is to move a food from the serving location to the plate or mouth). The work by Levitz (1976) and Meyers, Stunkard, and Coll (1980) referred to above suggests that modest changes in positioning of foods can influence food intake.

All of the successful manipulations in accessibility referred to here were shown to be effective in single meals. We do not know whether people would compensate for the reduction in intake subsequently, by increased food intake, decreased exercise, or changes in efficiency of utilization of energy. This is addressed in the discussion.

The present studies explore the effects of small, usually unnoticed environmental changes. These changes are called nudges (Thaler & Sunstein, 2008) because they subtly encourage consumption of less calorie-dense food without altering the choice set. Hence our title: Nudge to Nobesity I. A companion paper, Nudge to Nobesity II (Dayan & Bar-Hillel, 2011) instantiates nudges by manipulating order of presentation of items on a menu in a real world setting, and reports increased intake of items presented at the top or bottom of a food category list, as opposed to middle positions.

We operationalize accessibility as proximity (i.e., requiring a longer or shorter reach) in three studies, and in a fourth study we operationalize it as ease of transfer (i.e., how easy it is to move a food from one location to another).

1.1 General methods

All studies were conducted in a cafeteria in the University of Pennsylvania Health System. The cafeteria was open from 8am to 2pm on weekdays. Customers were primarily University of Pennsylvania Medical Complex employees. About a thousand people per day purchased items in the cafeteria.

Figure 1: Layout of self-serve, pay-by-ounce salad bar. Rows A & C are "edge" rows near the entrance and exit, respectively, and row B is the "middle" row, which can only be accessed by reaching over an edge row and underneath a clear plastic shield ("Sneeze Guard").

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	
Greens	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Dressings and condiments
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	

The pay-by ounce, self-serve salad bar was only open from 11am to 2pm. An average of 157 purchases per day were made from the salad bar. The bar was three rows deep, typically offered ten ingredients per row, and could be accessed from either side (Figure 1). Clear plastic shields ("Sneeze Guards") were over the array, as is common in salad bars, to prevent "contamination" from the mouth of the customer, or any other contamination from above. This made accessing the ingredients in the two outermost, edge rows somewhat difficult, and accessing ingredients in the middle row even more difficult, since the approach to middle trays required reaching further under the shield. Twenty-four ounce plastic bowls were available for the customers. Greens were offered on one end and dressings and condiments on the other. The layout is displayed in Figure 1

In all studies, we assisted in arranging and refilling the salad bar each day. Any target ingredient was weighed at the beginning of the day, whenever it was refilled, and at the end of the day using a scale accurate to 0.02 kg. The total consumption, in grams, was calculated for each ingredient. We obtained the number of customers who purchased salads from the salad bar through daily sales records. Total intake was divided by total number of salad purchases. This number—the average grams consumed per salad bar customer per day—was the dependent variable for all target ingredients.

In each study, the array of ingredients measured differs. Since it was practically unfeasible to track and measure all ingredients, we chose ingredients based on (1) the consistency with which they were stocked and (2) popularity. Due to budgetary and management changes in the cafeteria, different ingredients were consistently stockpiled at different times throughout the three-year period during which data were collected. At the beginning of each study, we discussed with management and staff which ingredients were stocked most consistently and which ingredients tended to run out by the end of the week. Then, of the ingredients which were judged to be consistently in stock, we chose the most popular ingredients. We reasoned that since popular ingredients were consumed by many customers, they were least likely to be affected by unusual eating behaviors of any one customer.

2 Study 1

2.1 Method

Our first study investigated whether proximity affected amount of food selected for purchase. Over the course of two months, we varied the location of eight ingredients—broccoli, shredded cheese, chicken, cucumbers, hard-boiled eggs, mushrooms, olives, and tomatoes. In the middle condition, an ingredient was located in one large tray in the middle row (which is ten inches less proximate and requires a longer reach, see Figure 2A, middle). In the edge condition, an ingredient was located in two small (half-sized), separate trays, one in each edge row (see figure 2A, edge). The distance from the greens (lateral positions 1 to 10 in Figure 1) of any particular food was constant across days and conditions. (The middle and edge conditions also differ in allowing one versus two opportunities for access, respectively—a difference which is explored in Study 2.)

We organized the salad bar in one of two arrangements each day. In arrangement one, chicken, cucumbers, eggs, and tomatoes were in the middle condition (located in the middle row) and the other four ingredients were in the edge condition (located in two small trays, one in each edge row). In arrangement two, chicken, cucumbers, eggs, and tomatoes were in the edge condition, and the other ingredients in the middle condition. To control for weekday, arrangements were alternated so that the salad bar was set-up in arrangement one on Monday, Wednesday, and Friday of week one and on Tuesday and Thursday of week two (the MWFTuTh pattern). If an ingredient was not available to customers at any point in the day, either because it ran out before it was refilled or because it was out of stock, then that day's datum for that ingredient was excluded.

2.2 Results

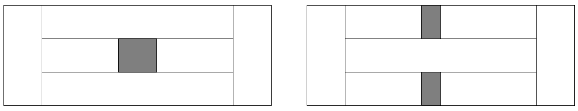
As displayed in Figure 2B, the average consumption from trays in the middle condition was less than the average consumption from the trays in the edge condition across all eight ingredients. The probability of all eight ingredients showing an effect in the same direction by chance is small ($p < 0.01$). The means and t-values for each specific food in the middle and edge condition, respectively, follow, in grams/person/day[1]: Broccoli: 5.5g, 6.9g ($t(36) = -2.34$, $p = 0.03$); Shredded cheese: 7.6g, 9.9g ($t(18) = -3.10$, $p = 0.01$); Chicken: 26.2g, 26.7g ($t(40) = -0.49$, $p = 0.63$); Cucumbers: 15.2g, 16.9g ($t(39) = -2.26$, $p = 0.03$); Eggs: 18.6g, 19.9g ($t(39) = -1.62$, $p = 0.12$); Mushrooms: 7.8g, 9.2g ($t(40) = -2.55$, $p = 0.01$); Olives:

[1] All statistical tests on specific foods were two-tailed, independent t-tests which were not Bonferroni-corrected.

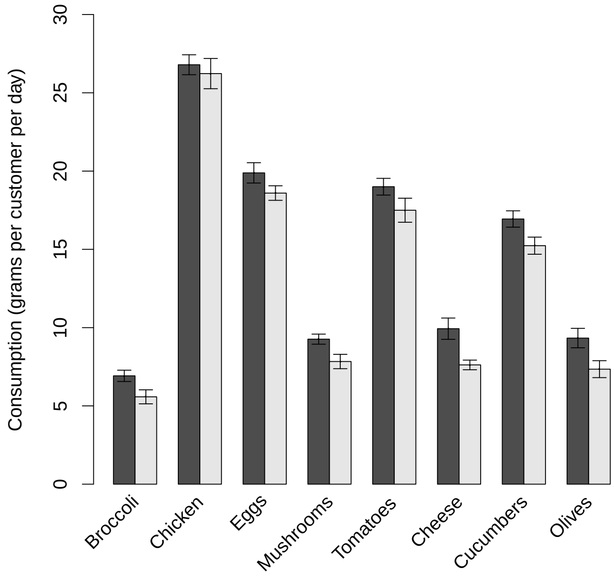
Figure 2: Specific layout for Study 1. A. Middle: Location of an ingredient in the middle condition. Edge: Location of an ingredient in the edge condition. B. In Study 1, average grams consumed per salad bar customer per day of an ingredient and standard errors, as a function of location. Dark bars represent consumption from the edge (accessible) locations, and lighter bars represent consumption from the middle (inaccessible) location.

(A)

Middle: Edge:



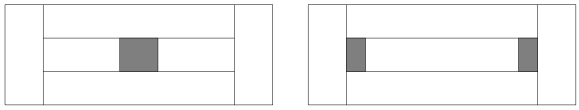
(B)



7.4g, 9.3g ($t(24) = -2.41$, $p = 0.02$); Tomatoes: 17.5g, 19.0g ($t(32) = -2.61$, $p = 0.12$). Each sample size reflects the number of days where an observation that met our criteria (in grams/person/day consumed of that ingredient) was recorded. Next, we normalized intake within each ingredient to adjust for different absolute levels of consumption of each ingredient. We determined the mean z-score of an ingredient's consumption for both middle and edge conditions. For each ingredient, its mean consumption in the edge condition minus its mean consumption in the middle condition was calculated, and these eight z-score differences were subjected to statistical analysis. The average difference in intake (edge-middle) across the eight foods was a z-score value of 0.68, significantly different from zero ($t(7) = -6.317$, $p < 0.001$). Using the edge, accessible condition as a baseline, average intake reduction of an ingredient in the inaccessible condition was 13.4%.

Figure 3: Specific layout for Study 2. One Opportunity: Location of an ingredient which had one opportunity for access. Two Opportunities: Location of an ingredient which had two opportunities for access.

One opportunity: Two opportunities:



3 Study 2

We designed our second study to isolate the effects of the number of opportunities to encounter a food on intake. Edge positions in study one allowed an ingredient to be more easily accessed for two reasons. First, edge rows are more accessible than middle rows. Middle rows require a small additional effort of reaching over an edge row. Second, since the edge food was presented on both edges, there were two opportunities to directly encounter it. Technically, both conditions in Study 1 present two opportunities for access. Two serving implements were available for each middle row tray, one pointed to each side, to ensure that customers could access the tray from both sides. Since customers nearly always circle the salad bar, in Study 1 they have two opportunities to access both an edge row and the middle row, one opportunity as they pass each edge. However, two separate trays may draw more attention to the multiple opportunities for access.

3.1 Method

In the second study, an ingredient was either presented in one large tray in the center of a given row (as in Figure 3A, one opportunity), or in two separated, small trays at the ends of that same row (as in Figure 3A, two opportunities). We always presented cucumbers in row A, chicken and bell peppers in row B, and eggs in row C (Figure 1), and every ingredient alternated being presented in one large tray and in two small trays within its respective row. Over the course of eleven weeks, we organized the salad bar in one of two different arrangements. In arrangement one, cucumbers and chicken were each located in two small trays at the ends of rows A and B respectively, while bell peppers and eggs were each located in one large tray in the middle of rows B and C respectively. In arrangement two, cucumbers and chicken were located in one large tray in the center of rows A and B respectively, while bell peppers and eggs were located in two small trays at the ends of rows B and C respectively. Once again, arrangements were alternated in a MWFTuTh pattern. Exclusion criteria for data were the same as in Study 1.

3.2 Results

Presenting an ingredient in two trays reduced average intake for chicken and bell peppers and increased average intake for cucumbers and eggs. The means and t-values for each ingredient when there was one opportunity for access (one large tray) and two opportunities for access (two small trays), respectively, follow in grams/person/day[2]: Chicken: 28.9g, 27.0g ($t(42) = 1.05$, $p = 0.20$); Cucumbers: 16.6g, 17.8g ($t(45) = 0.73$, $p = 0.19$); Bell peppers: 12.3g, 11.4g ($t(44) = 0.43$, $p = 0.07$); Eggs: 20.4g, 21.0g ($t(45) = 0.53$, $p = 0.37$). For each ingredient, differences in consumption were not significant. In fact, contrary to this alternative hypothesis, presenting an ingredient in two trays as opposed to one tray actually reduced intake by an average of 1.33%.

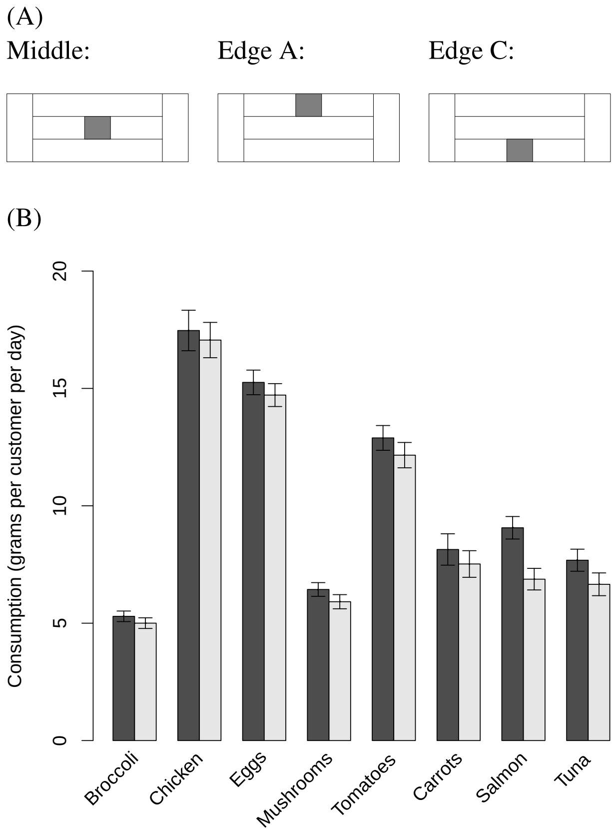
4 Study 3

Study 1 showed that middle location reduces intake, and Study 2 eliminated the possibility that this was because the two simultaneous edge locations allowed for two salient opportunities for easier access. However, it is still possible that in some way, the two easier access edge opportunities contributed to the edge advantage. In Study 3, we eliminate this possibility by presenting a food on any given day in the middle row or at only one edge. In fact, this set-up technically allows two opportunities to access the middle tray (once from each side of the salad bar), but only one opportunity to access the edge tray.

4.1 Method

We varied the locations of eight different ingredients—chicken, eggs, tuna, salmon, tomatoes, carrots, mushrooms, and cucumbers. We followed the same weighing and exclusion procedures that we used in Studies 1 and 2, except that we also eliminated any datum indicating less than 0.15 kilograms of total daily consumption of an ingredient. Since 0.15 kg is *way* below normal consumption levels, we assumed that a staff member had refilled the tray without our knowledge. Additionally, if two or more ingredients fit this specific exclusion criterion, the entire day's data were discarded.[3] Over the course of six months, we set the salad bar each day in one of four different arrangements. In arrangement 1, salmon and broccoli were at edge A, carrots and tuna were at edge C, and chicken, mushrooms, eggs, and tomatoes were in the middle (Figure 1). In arrangement 2, chicken and mushrooms were at edge A, eggs and tomatoes were at edge C, and salmon, broccoli, carrots, and tuna were in the middle. In arrangement 3, carrots and tuna were at edge A,

Figure 4: Specific layout for Study 3. A. Middle: Location of an ingredient in the middle condition. Edge A: Location of an ingredient at edge row A (near the entrance). Edge C: Location of an ingredient at edge row C (near the exit). B. In Study 3, average grams consumed per salad bar customer per day of an ingredient and standard errors, as a function of location. Dark bars represent consumption from the edge (accessible) locations, and lighter bars represent consumption from the middle (inaccessible) location.



[2] All statistical tests on specific foods were two-tailed, independent t-tests which were not Bonferroni-corrected. Each sample size reflects number of days, where an observation that met our criteria, in grams consumed per person per day, was made.

[3] At the beginning of Study 3, changes in staff and management personnel caused some confusion at the cafeteria. On a few occasions, new staff members refilled multiple trays on the salad bar without experimenters weighing and tracking the changes. Adding new exclusion criteria took account of these changes, though an analysis of the data using only exclusion criteria from Studies 1 and 2 yields the same direction and levels of significance in our two-way t-tests.

salmon and broccoli were at edge C, and chicken, mushrooms, eggs, and tomatoes were in the middle. In arrangement 4, eggs and tomatoes were at edge A, chicken and mushrooms were at edge C, and salmon, broccoli, carrots, and tuna were in the middle. Thus, half of the time an ingredient was in the middle condition (in one large tray in the middle row, as in Figure 4A, Middle). The other half of the time, the ingredient was in the edge condition and alternated between being presented in edge row A and in edge row C (Figure 4A, Edge A and Figure 4A, Edge C respectively). The size of the container for a particular food was always the same whether presented in the middle or edge position. The lateral position (positions 1 to 10 in Figure 1) for any particular food was also held constant. Possible weekday differences were also of concern. We displayed five arrangements each week, cycling through arrangement one, two, three, four, and back to one. The following week would begin with arrangement two, and so on.

4.2 Results

Average intake of each of the eight ingredients diminished when displayed in the middle row as opposed to one edge row (Figure 4B). That eight of eight ingredients showed this effect in the same direction is significant ($p < 0.01$). The means and t-values for each ingredient when displayed in the middle row and edge row, respectively, follow, in grams/person/day[4]: Chicken: 17.1g, 17.5g ($t(63) = -0.35, p = 0.36$); Eggs: 14.7g, 15.3g ($t(69) = -0.75, p = 0.25$); Salmon: 6.9g, 9.1g, ($t(66) = -3.30$, $p < 0.001$); Tuna: 6.7g, 7.7g ($t(51) = -1.52$, $p = 0.07$); Tomatoes: 12.2g, 12.9g ($t(64) = -0.97$, $p = 0.17$); Carrots: 7.5g, 8.1g ($t(50)$ =,-0.70, $p = 0.24$); Broccoli: 5.0g, 5.3g ($t(67) = -0.91$, $p = 0.18$); Mushrooms: 5.9g, 6.4g ($t(59) = -1.24$, $p = 0.11$). A t-test on the differences in mean intakes of each ingredient from the middle versus the edge, after again normalizing values within each ingredient (as with Study 1), revealed a significant reduction in intake from the middle row (mean z-score difference = 0.30, $t(7) = -4.13$, $p < 0.01$). Intake was reduced by an average of 8.9% when an ingredient was located in the middle as opposed to one edge row. Since this study was carried out over six months (with some interruption) with up to 69 days of data collection, it is conceivable that subjects adapted to the changes (a novelty effect). We examined the data for this possibility and saw no evidence for this effect.

[4]All statistical tests on specific foods were one-tailed, independent t-tests which were not Bonferroni-corrected. One-way tests were conducted because Studies 1 and 2 established one directional hypothesis of interest (i.e., that more food is selected from the edge than from the middle). Each sample size reflects number of days, where an observation that met our criteria, in grams consumed per person per day, was made.

5 Study 4

Our final study is based on the assumption that accessibility is not just a function of proximity. We hypothesized that the ease with which a utensil can convey a food to one's plate affects intake. Specifically, we varied the serving utensil: spoon versus tongs. We did not hypothesize which utensils would encourage more intake for each of the foods.

5.1 Method

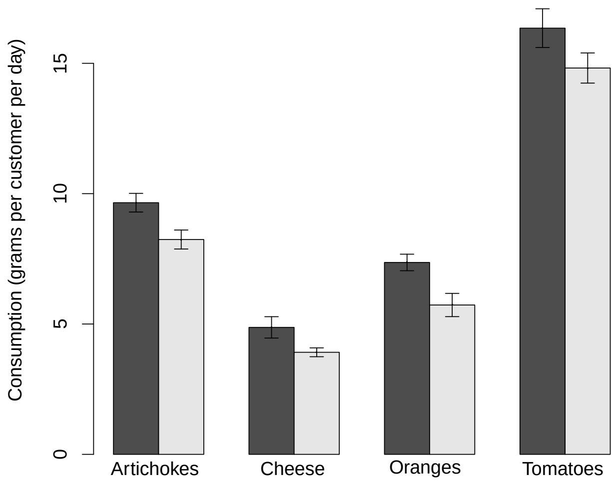
We measured four ingredients at the salad bar—tomatoes, artichoke hearts, mandarin oranges, and cheddar cheese cubes. The tomatoes were small, grape tomatoes. The artichoke hearts were cut into quarter segments and in oil. The mandarin oranges were individual segments in juice. Cheese cubes were about 1 cm^3. Over the course of eleven weeks, we followed the same weighing and exclusion criteria as in Studies 1 and 2. In arrangement one, artichokes and oranges were served with spoons, while tomatoes and cheese cubes were served with tongs. In arrangement two, tomatoes and cheese cubes were served with spoons, and artichokes and oranges with tongs. Arrangements one and two were alternated in a MWFTuTh pattern to control for weekday differences. The flat, oval ends of the tongs measured 3 inches long by 1 inch wide. The spoon had a capacity of about 120 ml. The location of each ingredient in the salad bar array (row and left-right position) was constant, with oranges in position A3; artichokes, A2; cheese cubes, C7; and tomatoes, B7 and B8 (Figure 1).

5.2 Results

All ingredients were consumed less when served with a pair of tongs as opposed to a spoon (Figure 5). The means and t-values for each ingredient when served with tongs and with a spoon, respectively, follow, in grams/person/day[5]: Artichokes: 8.2g, 9.6g ($t(40) = -2.77$, $p < 0.01$); Oranges: 5.7g, 7.4g ($t(41)$ = -2.98, $p < 0.01$); Cheese cubes: 3.9g, 4.9g ($t(39) = -2.15$, $p = 0.04$); Tomatoes: 14.8g, 16.4g ($t(42) = -1.624$, p = 0.11). A t-test on the four mean consumptions with a spoon versus four mean consumptions with tongs, using values normalized within each ingredient (mean z-score difference = 0.69), revealed a significant difference ($t(3) = -8.9$, $p < 0.01$). The average intake reduction when consuming an ingredient with tongs as opposed to with a spoon was 16.5%.

[5]All statistical tests on specific foods were two-tailed, independent t-tests which were not Bonferroni-corrected. Each sample size reflects number of days, where an observation that met our criteria, in grams consumed per person per day, was made.

Figure 5: Study 4. Average grams consumed per salad bar customer per day of an ingredient and standard errors, as a function of serving utensil (ease of transfer). Dark bars represent consumption with a spoon, and lighter bars represent consumption with tongs.



6 General discussion

The objective of this paper was to examine the influence of minor changes in accessibility on food intake in a real-world situation. Of course, it is important to note that we did not measure food actually consumed, but rather food selected. It is also important to consider that, although we focus on the potential of our manipulations to create calorie deficits, manipulations of this type could also promote healthier eating by encouraging relatively more intake of fruits and vegetables.

Our finding from Studies 1 and 3 that the middle, less accessible salad bar position discourages food intake runs, in some sense, in opposition to a bias to select items from the middle of arrays (reviewed in Dayan & Bar-Hillel, 2011). In these studies, unlike ours, there is usually no effort cost to select from the middle. The complexity of the determinants in general of middle versus edge (or middle versus top-bottom) are discussed by Dayan and Bar-Hillel (2011) who also report a top-bottom versus middle advantage in one food-related situation: selections from lists on a menu.

Our results indicate a small but consistent relation between accessibility and greater food intake. Though seemingly trivial, the resulting changes in intake (ranging from 8% to 16%) have potentially substantial implications for weight reduction for the average person, under certain assumptions. Consider an individual who eats at the salad bar described in our study five days each week, except during three weeks of vacation (i.e., 245 days per year). We assume that a 3,500 kilocalories deficit creates one pound of weight loss (Wishnofsky, 1958) and that the customer's subsequent energy input/output and metabolic efficiency does not compensate for the lower food intake due to inaccessibility. With these assumptions, we can now calculate the cumulative, annual weight loss that implementing the arrangements in Studies 1, 3 and 4 would cause for an individual. In all calculations, the actual caloric densities and daily intakes of ingredients we measured in each study were used. For Studies 1 and 3, we calculated the total calories consumed per year for our regular customer with the higher-calorie ingredients (chicken, eggs, shredded cheese, and olives in Study 1 and chicken, eggs, salmon, and tuna in Study 3) at the edge and the lower-calorie ingredients in the middle. We compared this number with the total calories consumed per year with lower-calorie ingredients at the edge and higher-calorie ingredients in the middle. The total difference in caloric intake per year would be 3,527 kcal in Study 1 and 1,488 kcal in Study 3, which would translate into a 1.01 pound (0.46 kg) and a 0.43 pound (0.20 kg) body weight difference, respectively. For Study 4, we calculated annual caloric intake for our customer if higher-calorie ingredients (cheese cubes and oranges in juice) were served with spoons and lower-calorie ingredients were served with tongs, and we compared this to annual caloric intake if lower-calorie ingredients were served with spoons and higher-calorie ingredients were served with tongs. The total difference in caloric intake per year would be 1,049 kcal, which would translate into a 0.30 pound (0.14 kg) body weight difference. We also compared annual intake if all ingredients were served with spoons versus if all ingredients were served with tongs. The annual difference in caloric intake would be 1,557 kcal, which translates into a 0.45 pound (0.20 kg) body weight difference. Bearing in mind that the average annual weight gain for an adult American is in the range of 0.9 to 2.5 pounds a year, these manipulations would diminish weight gain to an extent that could have an impact on public health.

Of course, our calculations make a number of assumptions, none of which is addressed by our experimental design. We assume that: (1) there is no interaction between consumption of one food alternative and another at the time of the meal; (2) customers *consume* all that they select from the salad bar or consume a percentage that does not depend on the total amount selected; (3) single day effects on intake would continue throughout the year; (4) there is no compensation for a slightly smaller meal later in the day or week, by increased intake at other meals or decreased amounts of exercising, and (5) there is no metabolic adaptation manifested as increased efficiency at extracting calories when caloric intake is slightly reduced. While we believe all of these assumptions are reasonable, none has been unequivocally demonstrated.

There already exists evidence favoring four of our five assumptions. Compensatory interaction of intakes of different foods within the meal (1, above) with the net effect of canceling accessibility effects does not occur in the one study that measured this (Diliberti et al., 2004). When customers were presented with 50% more macaroni and cheese, they consumed 43% more. Additionally, customers consumed *more, not less*, of their side dishes when presented with more macaroni and cheese. These findings suggest that people do not compensate for an environmental manipulation on a food item, at least during the meal in which the manipulation is in place.

There is evidence that single day effects (3, above) would continue over long periods of time. In one study, for 11 days, participants in a laboratory setting were either served all their caloric food and beverages in a typical, baseline portion size or in a 150% portion size. Participants presented with increased portion size consumed more calories over 11 days, and showed this excess consumption to the same degree on day 11 as in the first days (Rolls, Roe, & Meengs, 2007).

Evidence also suggests that behavioral compensation (4, above) does not occur through increased subsequent intake or decreased energy output. Rolls, Roe, and Meengs (2007) showed no compensation for increased portion size of lunch entrees over an 11 day period. Levitsky and Pacanowski (in press) have shown that replacing lunch with a 250 kcal meal replacement over a 14 day period (on 10 week days) results in no significant changes during other meals during those days and no significant changes in hunger ratings before dinner. Most critically, Levitsky and Pacanowski (in press) found significant weight loss for the reduced lunch size group. No existing studies address whether changing energy intake causes compensation via exercise (though the weight loss in the Levitsky and Pacanowski study suggests that there is no compensation). However, studies do show that long-term changes in exercise output do not seem to cause compensation via energy intake (Blundell & King, 1999; Donnelly et al., 2003).

Compensation for lower caloric intake in a meal by metabolic adaptation (5, above), would negate body weight loss that was produced by an environmentally induced decrease in intake of a particular food or at a particular meal. Yet, as mentioned above, Levitsky and Pacanowski (in press) have shown that replacement of a normal lunch by a 250 kcal meal for 14 days results in a significant weight loss. Also, studies which do find metabolic adaptation generally involve large changes in daily intake.

Some environmental changes are easily implemented and have little cost. Furthermore, a shift by consumers to lower-calorie or healthier foods in restaurant/cafeteria settings should usually be revenue-neutral and hence acceptable to vendors. This makes the environmental changes very attractive because there is a natural partnership between public health aims and vendor aims.

We suggest that the most plausible mechanism to account for our effects is that people try to minimize the energy they expend in obtaining food. This account follows from both the idea of optimal foraging and from Tolman's Law of Least Effort. Tolman states that behavior "will always tend to occur with a minimum expenditure of physical energy" (Tolman, 1932, p. 448). It is clear that the edge location is more accessible and requires less energy to obtain food from it. The greater intake with spoon than tongs was not predicted, but is consistent. The simplest hypothesis to explain this is that these foods can be extracted more efficiently with spoons. Whatever the mechanism(s), the principle that accessibility affects food intake has potentially important public health implications. An alternative explanation of the mechanism of accessibility could be perceptual salience. At least for the position variations, it may be that the edge positions are more perceptually salient.

In order to fully understand the effects of environmental changes on food intake and determine the public health value of those effects, a study must be done examining the long-term effects (over at least months, if not years) of environmental manipulations on body weight. We hope this report will draw attention to the potential influence alterations to the food environment can have on eating behavior and the potential public health consequences of arranging the environment in a manner that nudges nobesity while still allowing consumers the freedom to choose.

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