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Original Research

Improvements in recall and food choices using a graphical method to deliver information of select nutrients

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ABSTRACT

Consumers have difficulty using nutrition information. We hypothesized that graphically delivering information of select nutrients relative to a target would allow individuals to process information in time-constrained settings more effectively than numerical information. Objectives of the study were to determine the efficacy of the graphical method in (1) improving memory of nutrient information and (2) improving consumer purchasing behavior in a restaurant. Values of fiber and protein per calorie were 2-dimensionally plotted alongside a target box. First, a randomized cued recall experiment was conducted (n = 63). Recall accuracy of nutrition information improved by up to 43% when shown graphically instead of numerically. Second, the impact of graphical nutrition signposting on diner choices was tested in a cafeteria. Saturated fat and sodium information was also presented using color coding. Nutrient content of meals (n = 362) was compared between 3 signposting phases: graphical, nutrition facts panels (NFP), or no nutrition label. Graphical signposting improved nutrient content of purchases in the intended direction, whereas NFP had no effect compared with the baseline. Calories ordered from total meals, entrées, and sides were significantly less during graphical signposting than no-label and NFP periods. For total meal and entrées, protein per calorie purchased was significantly higher and saturated fat significantly lower during graphical signposting than the other phases. Graphical signposting remained a predictor of calories and protein per calorie purchased in regression modeling. These findings demonstrate that graphically presenting nutrition information makes that information more available for decision making and influences behavior change in a realistic setting.

Abbreviations: ANOVA, analysis of variance; NFP, nutrition facts panel; NI, nutrition interest.

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1. Introduction

Diet-related diseases are prevalent in the United States, including obesity, diabetes, heart disease, and cancer [1]. Managing intake of specific nutrients is a primary method of treating or preventing these diseases [2], resulting in initiatives to make nutrient content of foods available to help individuals manage nutrient intake [3]. The predominant methods of communicating nutrition information in the United States are numeric. The nutrition facts panel (NFP) is required on packaged foods, and restaurants with 20 or more outlets must have nutrition information available for standard menu items and must numerically display calorie content on menus [4]. However, use of numeric information has been shown to be less effective than intended for both NFP [5] and restaurant calorie labeling [6,7]. This finding can likely be attributed to the available information not being well understood by consumers [8,9] and that use of nutrition information often occurs in time-constrained settings where other factors such as taste, price, or convenience can supersede the importance of nutrition [10,11].

Methods such as traffic light–style color coding exist to help consumers more easily interpret food content of specific nutrients in the context of dietary recommendations [12,13]. Although these methods are more effective at improving consumer understanding of food nutrient content than NFP [13], studies that actually measure their impact on behavior in realistic settings are limited and inconsistent [12,14]. Implementation of a traffic light system that color coded content of 4 nutrients (total fat, saturated fat, sodium, and sugar) in United Kingdom grocery stores showed no effect on consumer purchases [15]. On the other hand, when a traffic light labeling system was used to indicate only calorie content of foods in a full-service restaurant, entrée calories purchased were significantly reduced, whereas numeric labels had no effect [16]. This limited body of evidence suggests that although color coding content of a specific nutrient in food shows promise, it may become too difficult to use in a time-constrained setting when multiple nutrients are color coded.

There is some evidence that graphically presenting nutrition information may be beneficial. Visualizing nutrient content of a food by placing a point representing a food's nutrient content along a line that represents the typical range of nutrient content for foods in the same category can help individuals interpret that information more effectively than numerical presentations in low-literacy consumers due to the comparative nature of food decisions [17]. Two-dimensional plots are widely used in numerous fields to visualize quantitative information for easy comparison. To our knowledge, however, there are no published studies that use a 2-dimensional plot to deliver nutrient information. Thus, it would be worth testing its efficacy in delivering nutrition information to be used for decision making.

The objective of this study was to determine the efficacy of using a 2-dimensional plot to present quantitative values of 2 select nutrients together with a target box representing recommendations for those nutrients. We hypothesized that this visual presentation of nutrient content of foods would allow users to more effectively process information for decision making in time-constrained settings than numerical information. Two studies were conducted to test this hypothesis. The specific objective of the first study was to determine if showing nutrition information graphically instead of numerically under time constraint improves the ability of users to process and recall that information in a simulated environment using a cued recall experiment. The specific objective of the second study was to determine if graphically presenting nutrition information allows it to be more effectively used for decision making in a realistic setting compared with numeric nutrition information. For this objective, a field experiment was conducted by signposting nutrition information graphically at the point of purchase in a cafeteria.

2. Methods and materials

2.1. *Presenting nutrition information of foods 2-dimensionally*

Fig. 1 shows a graphical display method we developed in an attempt to make nutrient information easier to use for decision making. Food content per calorie of nutrient 1 would be plotted on the *y* axis, whereas nutrient 2 would be plotted on the *x* axis. A target representing a range of dietary recommendations for these nutrients is present near the center of the plot to help users understand food content of these nutrients relative to their dietary recommendations and to facilitate food combinations that are balanced in the 2 nutrients. The chart is divided into color-coded regions to help users identify how easily foods fit into the target eating pattern. In addition, the amount of calories in a food or meal can be represented by the circle sizes of data points on the plot and/or can be presented numerically next to their respective data point on the plot without further interpretation, as calorie recommendations differ greatly between individuals (Fig. 1). By plotting nutrients on a calorie baseline, individual foods as well as combinations of foods into meals can be visualized in a single chart to aid meal formation (Fig. 1). Furthermore, using calories as the baseline to rate nutrient content of foods encourages choosing foods high in the nutrients of interest while keeping calories within a healthy range.

Although many nutrients are important for optimal health, the primary objective of this research was to evaluate the efficacy of the 2-dimensional display in communicating nutrient information. For this purpose, 2 nutrients relevant to a specific health focus were selected to display graphically. Fiber and protein were selected as the 2 nutrients to support a weight management focus. Fiber intake has strong inverse associations with body weight and body mass index (BMI) epidemiologically [18], which may be more attributed to increased inclusion of whole foods naturally rich in fiber [19,20] than specific effects of fiber on satiety and food intake [21]. Most studies have found strong support for modestly increased protein levels over a normal protein diet in improving body fat loss and retaining lean mass during weight loss [22] and also improving satiety even during an energy deficit [23]. However, other nutrients could be selected to present in the same way. Examples include saturated fat and sodium for heart disease, carbohydrates and fiber for diabetes, and calcium and vitamin D for bone health.

The fiber and protein recommendations represented by the target square are presented in Table 1. The minimum protein percentage was set slightly higher than the lower

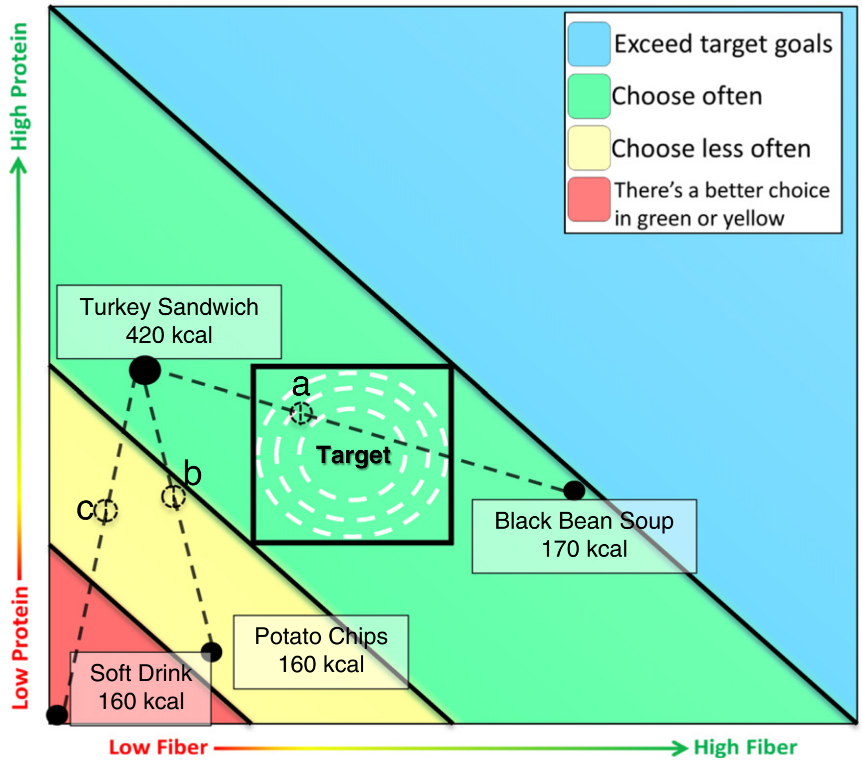

Fig. 1 – Graphical presentation of food nutrient content per calorie relative to recommendations. In this example, fiber (*x* axis) and protein (*y* axis) are selected as nutrients to plot based on criteria from Table 1. The target box represents the minimum criteria for fiber and protein (bottom left corner) to 2x the minimum (upper right corner). Regions are color coded to interpret nutrient content relative to target criteria. In the examples shown, the Turkey sandwich is high in protein but low in fiber, whereas the black bean soup is high in fiber and moderate in protein. Plotting nutrient/calorie allows the combination of individual foods into a meal to be visualized in the same chart. For example, addition of a cup of black bean soup pulls the meal into the target area (a), whereas addition of potato chips does not bring the meal into the target (b), and a soft drink would pull the meal farther away from the target area (c).

limit of the acceptable macronutrient distribution range to promote the benefits of increased protein intake during weight loss discussed above as well as to accommodate adequate protein intake for sedentary individuals whose total energy expenditure is low.

2.2. Design of recall accuracy study

We conducted a cued recall experiment that used a between-participants, first-pass design. University students were recruited via e-mail and flyer. Students were then randomized using computer-generated random numbers to either a visual group or a table group. Each individual was presented fiber and protein content per 418.6 kJ (100 kcal) of 30 different foods using an automated computer program and instructed to remember ratings for both fiber and protein for each food based on the nutrient content relative to target criteria. The 5 ratings of nutrient content were <1/2*x* minimum, 1/2-1*x*, adequate (1-2*x*), 2-3*x*, and >3*x*, where *x* represents the minimum criteria for fiber or protein presented in Table 1. The visual group was presented nutrition information of foods graphically on a 2-dimensional plot, which presented the ratings for fiber and protein as a grid

Table 1 – Nutrient content specifications used for target square (recall and café Studies) and half-circle color coding (café study only)

Nutrient	Range	Consensus recommendation [a]
Target square		
Fiber (g/100 kcal)	1.4-2.8	>14 g per 4186 kJ (1000 kcal)
Protein (% kcal)	16-32	10%-35% of total kcal
Color coding		
Saturated + transfat (% kcal)	Blue ≤ 10 < yellow ≤ 20 < red	<10% of total kcal
Sodium (mg/100 kcal)	Blue ≤ 100 < yellow ≤ 200 < red	<2300 mg per day [b]

[a] Compiled from Dietary Guidelines for Americans 2010 and Dietary Reference Intakes.
[b] Listed value refers to the Tolerable Upper Intake Level.

overlay on the color-coded plot. The table group was presented the same information numerically as a table which showed fiber and protein content of the food per 418.6 kJ (100 kcal) as well as the ratings those nutrient amounts correspond to relative to the target criteria to ensure both groups were provided the same information.

The study was performed via an automated PowerPoint presentation on a computer within an individualized booth for each study participant. Brief nutrition background including instructions on how to interpret and use the visual or table format was provided prior to the beginning of the task. Instructions described the role of fiber and protein in the diet and walked participants through how to interpret the nutrient content of a sample food using 2 steps: (1) where to find information for fiber and protein (eg, which row of table or which axis of plot) and (2) how to assign ratings for fiber and protein content (eg, which numeric ranges or which areas of the plot represent <1/2x minimum, >3x minimum, etc). Only one additional slide was required to explain the graphical display of nutrition information than to explain the table display. Following the instruction, nutrient information of 30 food items was sequentially presented either in a graphical or numerical format. Each food item was shown for 15 seconds. Each participant was then given an answer sheet that listed the names and possible ratings of all 30 foods shown to participants and asked to circle the correct rating for both fiber and protein for each food. Number of correct answers was used as the outcome measure. A reference sheet depicting a blank example of the format that the food information was shown was also provided to them (visual or table). Participants were also asked to fill out a survey including age, sex, height, and weight, as well as to rate their nutrition knowledge from 0 (minimal) to 10 (excellent). Participants completed consent forms and were compensated with $10 for participation. This experiment was approved by the University of Illinois at Urbana-Champaign Institutional Review Board.

2.3. *Design of cafeteria study*

2.3.1. *Study setting*

A 12-week field experiment was conducted to determine the efficacy of graphically presenting nutrient information to improve healthfulness of consumer food decisions in a cafeteria on a university campus. The café uses a planned menu with different food offerings every day, cycling every 3 weeks. Four entrée options, 1 starch side, 2 vegetable sides, and 2 desserts are planned for each menu day. Greens and specialty salads, fruit cups, and yogurt parfaits are available every day in the cafeteria. The cafeteria uses an a la carte style setup; food displays are present for customers as they make their food decisions near the entrance of the café, and orders are placed at a register, followed by a line of salads and sides on ice that customers can add to their meal. All food items are paid for at a second register at the end of the line. Nutrition information for menu items had never been collected or displayed in the cafeteria prior to the study.

2.3.2. *Study design*

The study design consisted of signposting nutrition information at the point of purchase in the cafeteria using either an NFP or graphical format in the cafeteria (Fig. 2) and using sales data as a metric to measure change in purchasing behavior. The 12-week experiment was divided into four 3-week phases based on the café's rotating menu cycle to minimize variations in food offerings between the phases (Fig. 3). No nutrition information was signposted during the baseline phase to establish values for normal sales of menu items before introduction of nutrition information into the cafeteria. Because nutrition information

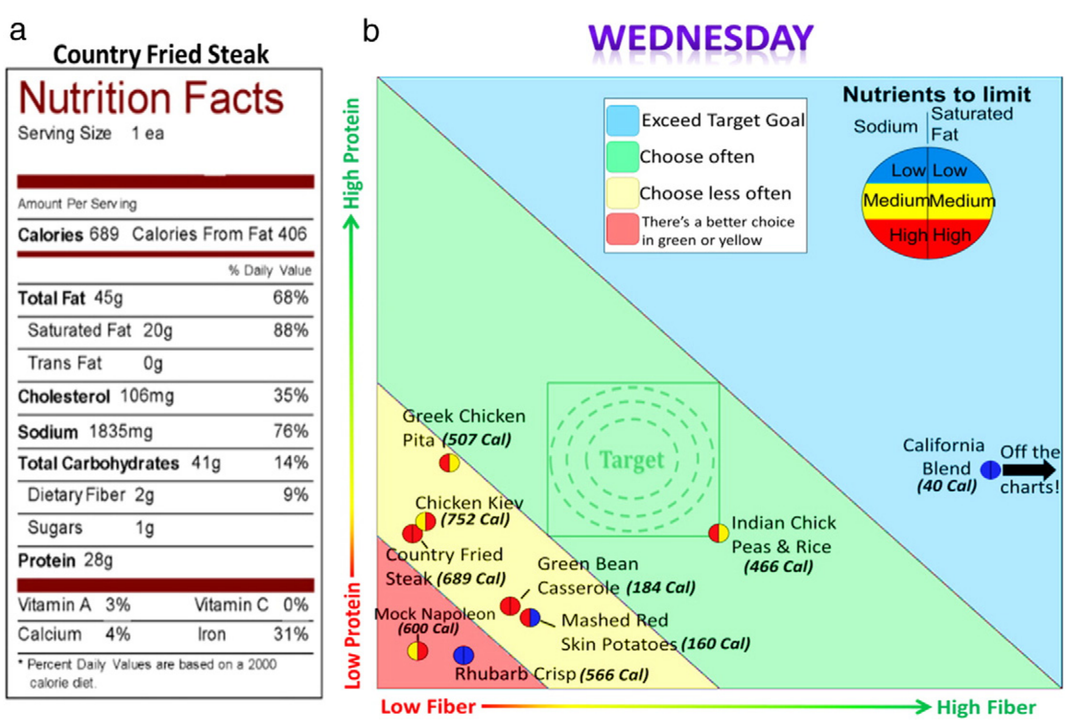

Fig. 2 – Examples of signposting nutrition information at point of purchase in cafeteria for NFP phase (a) and graphical phase (b).

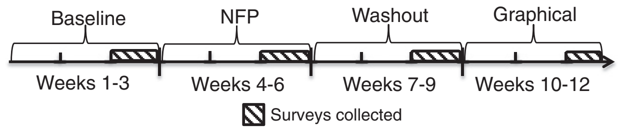

Fig. 3 – Study timeline based on cafeteria's repeating 3-week menu. Each phase consisted of one 3-week menu cycle to ensure the same foods were offered during each phase. Data were collected during the third week of each study phase.

had never been signposted in the cafeteria before, it was first presented using NFPs. This phase served 2 purposes: (1) to understand how consumers respond to being shown food content of the nutrients of interest when they are presented without graphical interpretation and (2) to minimize any novelty effect of the initial introduction of nutrition information into the cafeteria from confounding specific effects of use of the graphical signposting method (Fig. 3). A second 3-week baseline (washout) period occurred between phases during which no nutrition information was presented to minimize the effects of NFP signposting carrying over into the graphical signposting phase.

During the NFP phase, nutrition information for available menu items was placed next to each item's display immediately prior to where customers place their order in an NFP-style format (Fig. 2a, Supplementary Fig. 1A). During the graphical signposting phase, all menu items planned for the day appeared together on a single plot on a poster next to food displays (Fig. 2b). In addition to presenting fiber and protein per calorie 2-dimensionally as in the recall study, data points were color coded using half circles based on saturated fat and sodium content per calorie of foods to determine if content of additional nutrients could be effectively communicated using the graphical format (Fig. 2). Ratings were based on nutrient recommendations for these nutrients to reduce the risk of heart disease and stroke [24], where blue (low) represented content below the target recommendation from Table 1, yellow (medium) represented content between 1-2*x* the target recommendation, and red (high) represented >2*x* the target recommendation (Table 1 and Fig. 2). All items that were offered every day in the cafeteria appeared together on an additional plot next to the first to allow it to be reused every day (Supplementary Fig. 1B).

During each study phase, printed instructions on how to use the respective signposted nutrition information (Supplementary Figs. 2 and 3) were displayed next to the displayed nutrition information prior to purchase. However, patrons were not specifically asked by the study team to use the nutrition information or change their purchasing behavior; there was no interaction between the study team and participants until patrons completed their purchase and accepted the survey. During graphical signposting, the printed instructions showed an example of how to select the food closest to the target, how foods can combine to form a meal, and why each nutrient was important to consider (Supplementary Fig. 2). To ensure customers of the cafeteria during the NFP phase received a similar level of instruction to those dining during the graphical phase, instructions describing how to use the NFP to manage a healthy weight were posted next to food items during the NFP phase (Supplementary Fig. 3). The instructions used a sample NFP to emphasize the same ideas seen in the graphical presentation of nutrition information: keeping calories in a healthy range, limiting sodium and saturated fat, and increasing fiber and protein, as well as the recommended daily values for these nutrients.

2.3.3. *Calculations of nutrient values of menu items*

Nutrition information for each menu item in the café was determined using the café's recipe database and manufacturer-provided information for ingredients used in recipes. The US Department of Agriculture National Nutrient Database for Standard Reference was used for items whose information is not provided by the manufacturer. Signposted items were categorized by the researchers as entrées, side items, or desserts. The cafeteria also offers the following items that are prepared the day of production: "daily special" entrée, featured salad, side salad (pasta or mayonnaise based salads), soup du jour, and student test recipes. Because these dishes are not known in advance and many are prepared without recipe, nutrition information for these items could not be compiled and shown to customers.

2.3.4. *Data collection*

During the final week of each study phase, patrons were asked to provide their lunchtime meal receipt and complete a survey (Fig. 3). Café patrons were provided information about the study when they paid for the meal, and willing participants would come to a booth where surveys were distributed. Surveys for all 4 phases included frequency of dining, sex, height, weight, education, age, and household income as demographic information. Interest in nutrition labels as well as which specific nutrients are of importance, interest in weight loss, and factors going into food decisions were also included. For the experimental phases, participants were asked to what degree nutrition information influenced their purchase.

Patron sales receipts from the lunchtime meal were attached to their survey, and the meal's nutrient content was determined by summing nutrient values of items whose information was available to be signposted. Nutrient compositions of meals as well as survey characteristics were then compared pairwise between both experimental phases and the no-label phases. Meals containing any food item whose nutrition information was not available to be signposted, such as daily specials, were excluded from analysis, as an accurate assessment of the nutrient content of these meals could not be made.

A final variable of interest, which was specific to the graphical phase of the experiment, was how well patrons understood the graphical method of presenting nutrition information. To determine subjective understanding, patrons were asked to indicate their level of agreement with the statement "I understood the nutrition graph." Objective understanding was determined by including a sample plot on the survey in addition to 5 multiple choice questions requiring specific interpretation of the plot. Patrons were asked to identify a food low in sodium and high in saturated fat, which entrée was lowest in calories, which food was rated highest in fiber, which was rated highest in protein, and a question requiring basic understanding of the properties of how foods combine to form a meal on the nutrition plot as shown in Fig. 1 to help determine which aspects were most well understood.

Participants were compensated with a $2 gift card for the cafeteria and were only allowed to complete the survey once during each study phase. This study was approved by the University of Illinois at Urbana-Champaign Institutional Review Board.

2.4. Statistical analyses

All analyses were performed using PASW statistics version 18 (SPSS Inc, Chicago, IL, USA), with statistical significance defined by an α of .05.

2.4.1. Recall accuracy

To analyze results of the cued recall experiment, recall accuracy was measured by calculating the number of correct responses for fiber, protein, or both fiber and protein for a food (30 possible), for each individual. Correct response data are presented as means ± SD and compared between groups using an independent t test. A sample size of 25 participants in each treatment allowed for detection of effect sizes of more than 0.4 with 90% power using an independent t test. A total of 63 students completed the study. Outliers (n = 2) were removed on the basis that their mean squared deviation from the correct answer was greater than random guessing; the most likely cause of the outliers was entering answers for fiber and protein in wrong columns on the answer sheet.

2.4.2. Survey data

During data collection of the cafeteria field experiment (week 3 of each phase), all patrons willing to submit their surveys and receipts were accepted. A goal of 100 receipts collected within each study phase was set, which allowed for detection of effect sizes of more than 0.4 with 80% power using a 1-way analysis of variance (ANOVA) test for the primary outcome of nutrients purchased. Number of surveys able to be collected was limited by the traffic of the cafeteria, which typically serves between 100 and 200 individuals per day.

A total of 696 meal receipts and surveys were collected from patrons during the study period. Respondents who ordered a food item whose nutrition information was not signposted were excluded from analysis (n = 334), bringing the final sample size to 362. No significant differences in nutrient content were found between meals purchased during the baseline and washout phases, so these phases were combined

Table 2 – Characteristics of study population [a]

Variable	No label [b] (n = 209)	NFP (n = 79)	Graphical (n = 74)
Demographic			
Female	59%	56%	62%
Age 18-24 y	21%	32%	19%
Age 25-34 y	38%	38%	45%
Age 35-60 y	35%	25%	26%
Age 60+ y	6%	5%	11%
Overweight or obese (BMI > 25 kg/m^2)	43%	42%	46%
Undergraduate student	12%	17%	18%
Graduate student	31%	44%	34%
Staff	36%	22%	34%
Faculty	17%	14%	8%
Other	3%	4%	7%
Education (at least some college or more)	96%	99%	97%
Frequent diners [c]	63%	72%	70%
NI			
Use nutrition labels when shopping [d]	84%	87%	86%
Consciously monitoring weight [d]	75%	73%	76%
Monitoring daily calories [d]	56%	52%	59%
Would/did value nutrition information in café [d]	85%	87%	89%
Sum of above 4 responses (range 0 [lowest] to 16 [highest]) [e]	11.5 ± 3.0	11.6 ± 2.7	11.9 ± 3.0
Purchase characteristic			
Put considerable thought into purchase [d]	68%^{x,y}	58%^{x}	77%^{y}
Taste most important	60%	60%	69%
Health most important	25%	27%	22%
Price most important	9%	9%	5%
Recommendation most important	1%	4%	4%

Unmarked variables are categorical and presented as percentage of respondents falling within each category.
[a] Superscripts x and y denote significant difference between groups (χ^2 test for categorical variables, ANOVA for continuous variables; $P < .05$).
[b] Baseline and washout conditions were combined into one no-label category, as no significant differences were found in nutrients purchased between these conditions.
[c] Patrons visiting at least once/week.
[d] Sum of agree or strongly agree.
[e] Continuous variable presented as means ± SD.

into a single "no-label" group for analysis. The number of patrons ordering a non-signposted item did not differ between study phases.

For survey questions that asked participants to rate their level of agreement to a statement using a Likert scale, a proportion of those agreeing or strongly agreeing to a statement are shown. All categorical survey variables, which included all variables except for the nutrition interest (NI), were analyzed using a χ^2 test, and column proportions were compared between study conditions using z scores with Bonferroni corrections. Variables relating to NI were combined as a summary determinant-labeled NI by summing the values of an individual's Likert scale responses to 4 questions regarding nutrition label use when shopping, consciousness of monitoring weight, monitoring of daily energy intake, and perceived value of nutrition information in the cafeteria. Nutrition interest had a range of 0 (lowest) to 16 (highest) (Table 2). This construct had a Cronbach α of .72. Nutrition interest is shown as means ± SD and was compared between groups using ANOVA.

2.4.3. *Patron meal choices*

To determine overall patron meal purchasing behavior, means ± SD for total calories and nutrients purchased from signposted items per survey participant meal were analyzed and compared between study phases using ANOVA. This measurement primarily reflects the sum of choices made by patrons when deciding on a meal, including which item to order as well as whether or not to order a certain item type, such as a side or dessert. Data for sales of entrees, side items, and desserts were individually analyzed in addition to total meal purchases. To account for the patrons who did not order an item from a certain food category, a value of 0 calories or nutrients purchased from that respective category was assigned to that meal to reflect the choice made to abstain from ordering that item. A proportion of patrons electing to order each item type (entrée, side, dessert) were compared between conditions using χ^2 analysis. Pairwise comparisons were completed using Bonferroni post hoc analysis.

2.4.4. *Nutrient content of selected items*

As the 2 nutrients plotted 2-dimensionally (fiber and protein per calorie) were the primary interest of the study, means ± SEM for fiber and protein content per calorie of items ordered were also analyzed to see if signposting led to selection of items more highly rated on the plot. The means ± SEM for protein and fiber content per calorie of total meals, entrées, sides and deserts were calculated for each individual using data from meal receipts and analyzed by ANOVA. Pairwise comparisons were completed using Bonferroni post hoc analysis.

2.4.5. *Determinants of nutrients purchased*

Determinants of nutrients purchased were analyzed using multiple regression with mean calories ± SEM or nutrient content per calorie of food items purchased per receipt ± SEM as the dependent variable. Survey determinants included in the model can be grouped into 3 categories: demographic, NI, and purchase characteristics (Table 2). One variable which is not included in this regression is education level, as the variable showed little variation (98% of participants indicated *at least some college* or more as education level). Initial regression analyses revealed no significant effect of education level on calories or nutrients purchased, so we opted to remove it from our final model specification. However, our university affiliation variable, which did show significant effect on nutrients purchased in initial regression analyses (student, faculty, staff, etc) still likely detects differences in education, should they exist.

The equation used to model calories purchased (total, entrée, side item, and dessert calories purchased were each modeled) or nutrient amount purchased by individual *i* is below. β_0 refers to the intercept, whereas $\beta_1 \ldots \beta_{16}$ refer to the effects of the respective variables listed in Table 2 on nutrient content of meals.

$$\begin{aligned}\text{Calories(Nutrient) Purchased}_i &= \beta_0 + \beta_1\text{Graphical}_i + \beta_2\text{NFP}_i \\ &+\beta_3\text{Freq}_i + \beta_4\text{Female}_i + \beta_5\text{Overweight}_i + \beta_6\text{Purchase Thought}_i \\ &+\beta_7\text{NI}_i + \beta_8\text{Taste}_i + \beta_9\text{Health}_i + \beta_{10}\text{Age25-34}_i + \beta_{11}\text{Age35-60}_i \\ &+\beta_{12}\text{Age} > 60_i + \beta_{13}\text{Undergraduate}_i + \beta_{14}\text{Graduate}_i \\ &+\beta_{15}\text{Staff}_i + \beta_{16}\text{Faculty}_i + \varepsilon_i\end{aligned}$$

2.4.6. *Correlations between nutrients*

Correlation statistics were calculated to determine if the amount of a nutrient purchased was related to the amount of a second nutrient purchased for patrons ordering a food within a respective menu category. Spearman rank correlation tests were used (Shapiro-Wilk normality test, $P < .05$).

2.4.7. *Understanding of graphical signposting*

Subjective understanding was analyzed by comparing the amount of participants who somewhat or strongly agreed with the statement "I understood the nutrition graph" to the amount of participants who either somewhat or strongly disagreed or failed to agree/disagree. Objective understanding was analyzed by determining the number of multiple choice

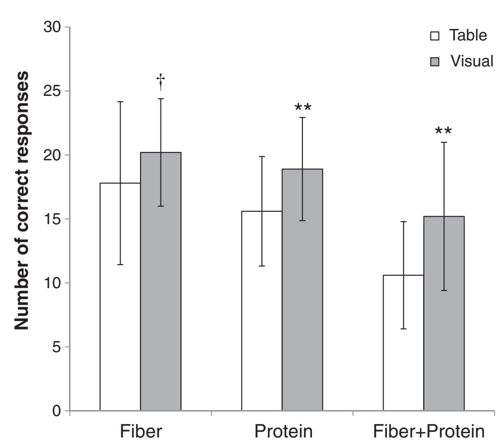

Fig. 4 – Comparison of recall accuracy of nutrition information between individuals shown nutrient content of foods using a table format and individuals shown using a graphical format. Participants were randomized to a table group (n = 30, open bar) or a graphical group (n = 31, gray bar) and shown fiber and protein content of 30 foods for 15 seconds per food. Data are presented as means ± SD. **Statistically significant (P < .01, independent t test). †Approached statistical significance (P = .085).

questions requiring use of the nutrition plot which were answered correctly.

3. Results

3.1. Cued recall study

There were no significant differences between groups for age, weight, BMI, nutrition knowledge, or sex distribution. As seen in Fig. 4, recall of correct fiber ratings and protein ratings were improved in the visual group. Participants in the visual group provided an average of 18.9 ± 4.0 correct answers (63% correct) for protein ratings for food, which was 21.2% greater than the number of correct protein responses provided by participants in the table group ($P < .01$), who provided an average of 15.6 ± 4.3 correct answers (52% correct). The number of correct answers for fiber was also improved in the visual group by 13% (20.2 ± 4.2 vs 17.8 ± 6.4 correct answers for visual and table, respectively), although this comparison only approached significance ($P = .085$). The difference between visual and table group accuracy was even greater when both fiber and protein ratings of a food were considered. Participants in the visual group showed 43% greater recall accuracy of fiber + protein ratings, recalling an average of 15.2 ± 5.8 (50.7%) of 30 correct answers for both nutrients compared with an average of 10.6 ± 4.2 (35.3%) of 30 for the table group ($P = .001$).

The improved recall seen in study I for individuals shown graphical information compared with those shown numeric information suggests that the graphical information was more effectively processed and committed to short-term memory under time constraint, showing promise for 2-dimensionally presenting nutrient values as a means of improving communication of nutrition information to consumers. However, nutrition information can fall secondary to taste or price when consumers are making food purchase decisions [8]. Thus, it is important to determine whether this graphical system can improve food choices in a realistic setting where factors such as taste, price, and even food appearance are simultaneously being considered by diners. Therefore, our next aim was to evaluate the efficacy of this graphical method to elicit behavior change in a realistic setting.

3.2. Cafeteria study

3.2.1. Characteristics of study participants

Characteristics of cafeteria patrons are presented in Table 2. No significant differences for any variables included in analysis were found between diners among the different study phases except for "put considerable thought into purchase," which participants agreed with more often on their surveys during the graphical phase than the NFP phase ($P = .04$). In general, the sample population was well distributed between sex, age group, weight status, and affiliation. The cafeteria uses fixed prices for each category of menu item, accounting for the low proportion of patrons listing price as a factor in their purchase decision. Most patrons ate lunch in the cafeteria at least once a week, allowing for repeated exposure to each signposting format. Self-reported nutrition label use by patrons was 85% and represents that of the general population, which is also 85% [25]. Patrons scored an average of 11.6 ± 2.9 of 16 for NI. Calories, total fat, and sodium were most consistently ranked in the top 3 nutrients of interest on surveys by participants (71.2%, 49.6%, and 27.8% of patrons ranking nutrient in top 3, respectively), whereas protein and fiber were ranked fifth and eighth, respectively (Supplementary Table 1).

3.2.2. Effect of signposting on nutrient content of patron meals

A summary of meals ordered by patrons is shown in Table 3. Most patron meals contained an entrée during each study phase (Table 3). The proportion of meals containing a side item was smaller, ranging from 50% to 62%. Few patrons ordered dessert during any study phase. The proportion of patrons ordering entrées, side items, or desserts did not differ significantly between study conditions.

Signposting information using NFP did not result in a change in calories purchased for total meal, entrée, side, or dessert calories compared with purchases when no nutrition labels were present (Table 3). However, signposting nutrition information using the graphical format resulted in 16% fewer total calories purchased per patron compared with sales when no

Table 3 – Number of meals containing entrée, side, or dessert items and nutrients purchased per meal based on diner receipts [a]

	No label (n = 209)	NFP (n = 79)	Graphical (n = 74)
No. of meals containing item type (%)			
Entrée	192 (92)	76 (96)	70 (95)
Side	122 (58)	49 (62)	37 (50)
Dessert	29 (14)	9 (11)	7 (10)
Mean calories ordered (kcal)			
Total meal	782 ± 23^{x}	827 ± 33^{x}	658 ± 32^{y}
Entrée	585 ± 15^{x}	632 ± 21^{x}	544 ± 28^{y}
Side	115 ± 10^{x}	131 ± 16^{x}	56 ± 9^{y}
Dessert	82 ± 15	63 ± 20	58 ± 21
Mean total protein ordered (g)			
Total meal	30.0 ± 0.8	33.3 ± 1.4	30.1 ± 1.2
Entrée	27.6 ± 0.8	30.4 ± 1.3	28.1 ± 1.2
Side	2.0 ± 0.2	2.6 ± 0.5	1.7 ± 0.4
Dessert	0.3 ± 0.1	0.3 ± 0.1	0.2 ± 0.1
Mean fiber ordered (g)			
Total meal	6.2 ± 0.3	6.6 ± 0.4	5.1 ± 0.3
Entrée	3.6 ± 0.2	3.6 ± 0.3	3.4 ± 0.3
Side	2.3 ± 0.2^{xy}	2.8 ± 0.4^{x}	1.5 ± 0.2^{y}
Dessert	0.3 ± 0.1	0.3 ± 0.1	0.2 ± 0.1
Mean saturated fat ordered (g)			
Total meal	15.0 ± 0.8^{x}	16.0 ± 1.2^{x}	10.0 ± 0.8^{y}
Entrée	11.8 ± 0.7^{x}	13.0 ± 1.1^{x}	8.0 ± 0.6^{y}
Side	1.3 ± 0.2^{xy}	1.5 ± 0.3^{x}	0.5 ± 0.2^{y}
Dessert	1.9 ± 0.4	1.4 ± 0.5	1.5 ± 0.6
Mean sodium ordered (g)			
Total meal	1313 ± 46	1273 ± 58	1289 ± 83
Entrée	1098 ± 36	1066 ± 49	1150 ± 79
Side	173 ± 19	183 ± 29	103 ± 26
Dessert	42 ± 10	24 ± 10	35 ± 14

Data are presented as frequencies or means ± SEM.

[a] Superscripts x and y denote significant difference between groups (ANOVA, $P < .05$).

nutrition information was present ($P < .01$) and 20% fewer calories purchased compared with NFP purchases ($P < .01$).

Changes in calories ordered from both entrées and sides purchased contributed to the changes in total calories ordered when information was signposted using the graphical format. The mean calories purchased from entrées during the graphical phase was 10% less than purchases when no label was present ($P < .05$) and 13% less than purchases when NFPs were present ($P < .01$). Side items showed a larger percentage difference in calories ordered between conditions, with the graphical phase showing 43% and 47% fewer calories ordered from side items compared with no-label and NFP conditions, respectively ($P < .001$). No difference was seen between calorie content of desserts ordered.

Despite the decrease in calories purchased during the graphical signposting, total grams of protein ordered per meal did not decrease, resulting in an overall increase in protein per calorie purchased consistent with the intent of the graphical signposting (Table 3). No difference in grams of fiber ordered for total meals or entrées was found between study conditions, although total fiber purchased from side items was significantly lower in the graphical condition than the NFP condition ($P < .05$), reflecting the lower number of patrons who purchased a side in the graphical phase. Total grams of saturated fat purchased per meal during the graphical condition was 38% and 33% lower than NFP and no-label conditions, respectively, which can be seen as changes in both entrée and side item saturated fat content (Table 3). Mean sodium purchased did not differ between conditions.

3.2.3. *Protein and fiber content per calorie of items selected by patrons*

Because a primary efficacy outcome of the study was to determine if the graphical signposting method led to selection of items that were more highly rated on the 2-dimensional plot, the protein and fiber content per calorie of consumer purchases is summarized in the 2-dimensional plot format in Fig. 5. The average protein content per calorie of meals purchased during the graphical phase was 25.2 g per 2093 kJ (500 kcal), which exceeds the target minimum for protein on the graph and was 23.8% greater than meals ordered when no label was present ($P < .001$) and 20.2% greater than meals ordered during the NFP phase ($P < .01$). This change largely came from increases in protein per calorie of entrées ordered, which was an average of 16.9% higher in entrées ordered during the graphical phase relative to the no-label phase ($P < .001$) and 16.5% higher relative to the NFP phase ($P < .01$) (Fig. 5). Fiber density per calorie did not significantly differ between conditions for total meals or entrées (Fig. 5). Although there was a numerical improvement of protein and fiber content per calorie of side items during graphical signposting compared with no-label and NFP signposting, the difference did not reach statistical significance (Fig. 5).

3.2.4. *Predictors of meal nutrient content based on regression analysis*

The regression results for total, entrée, side, and dessert calories purchased are shown in Table 4. Graphical signposting remained 1 of only 3 variables, alongside sex and NI, with a significant impact on total calories purchased. Relative to the no-label baseline, the graphical signposting condition resulted in 506 kJ (121 kcal) fewer purchase per person, on average. The change in total calories purchased during graphical signposting appears to be driven by a significant decrease in side-item calories purchased during this study phase (260 kJ [62kcal] fewer side-item purchase, on average). This decrease in calories purchased from side items is likely to a combined effect of lower-calorie side items being chosen by patrons (468.8 kJ [112 kcal] compared with 837.2 kJ [200 kcal] and 866.5 kJ [207 kcal] in no-label and NFP conditions, respectively, $P < .001$), and fewer patrons choosing to purchase a side item (50% compared with 58% and 62% in no-label and NFP conditions, respectively; Table 3) although the difference in percentage of patrons choosing to purchase a side item did not reach statistical significance between conditions ($P = .297$).

Nutrition interest also impacted calories purchased. Table 4 shows that for every 1-unit increase in NI (eg, a person is more interested in monitoring their weight, energy intake, etc), total calories purchased decreases by 76.6 kJ (18.3 kcal) per person, on average. The SD for NI was 3, whereas the range was 0 to 16, suggesting typical differences in NI accounted for a change of 230.3 kJ (55 kcal) but could account for up to 1222.3 kJ (292 kcal) between extremes. This effect appears to be strongest in the choice of main entrée, as the NI coefficients for side item and dessert calories are small in magnitude and statistically nonsignificant.

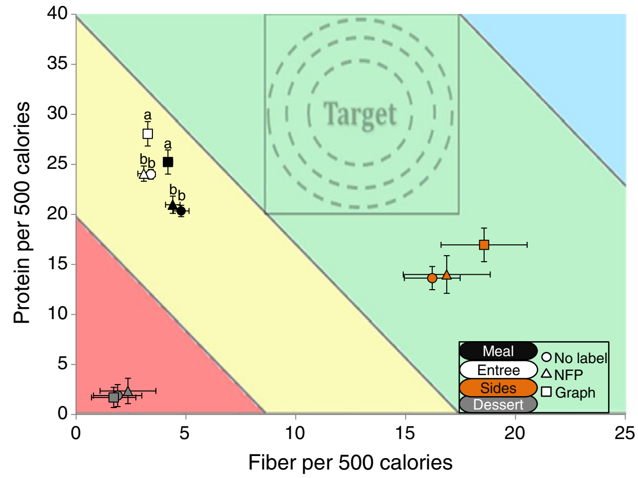

Fig. 5 – Effect of nutrition signposting in a cafeteria on the purchase of protein/calorie and fiber/calorie. Total meals (black), entrées (white), side items (orange), and desserts (gray). Nutrition information was signposted at the point of purchase using NFPs (weeks 4-6) or graphical signposting (weeks 10-12) and compared with purchases when no information was signposted (weeks 1-3 and 7-9). Nutrient content of purchased meals was determined using sales receipts collected during the third week of each treatment. Data are shown as means ± SE and presented using the same 2-dimensional format used in the graphical intervention. Letters indicate significant differences in protein (g) per 2093 kJ (500 kcal) between study conditions within each food category ($P < .05$, 1-way ANOVA). Fiber (g) per 2093 kJ (500 kcal) did not reach significant difference between study conditions for any food category.

Table 4 – Regression for predictors of total, entrée, side, and dessert calories ordered

Variable	Estimate (*B*)			
	Total	Entrée	Side	Dessert
Intercept	1053 **	768.4 **	172.7 **	111.6
	(119.4)	(86.2)	(54.6)	(81.1)
Graphical	−121.0 **	−40.2	−62.0 **	−18.8
	(40.6)	(29.3)	(18.6)	(27.6)
NFP	31.3	40.0	13.5	−22.2
	(39.8)	(28.8)	(18.2)	(27.1)
Frequent diner	−8.40	12.9	−7.7	−13.7
	(33.5)	(24.2)	(15.3)	(22.7)
Female	−125.0 **	−64.2 **	−50.2 **	−10.6
	(33.4)	(24.2)	(15.3)	(22.7)
Overweight or obese	65.9	23.0	22.9	20.0
	(34.9)	(25.2)	(16.0)	(23.7)
Considerable purchase thought	−46.5	−47.6	−3.2	4.3
	(38.0)	(27.4)	(17.4)	(25.8)
NI [a]	−18.3 **	−15.8 **	−2.6	0.1
	(6.2)	(4.5)	(2.9)	(4.2)
Value taste [b]	80.8	59.8	20.4	0.7
	(51.4)	(37.1)	(23.5)	(34.9)
Value health [b]	42.8	44.4	51.4	−53.0
	(57.5)	(41.5)	(26.3)	(39.1)
Age 2 (25-34 y) [c]	44.8	22.3	7.0	15.5
	(52.7)	(38.1)	(24.1)	(35.8)
Age 3 (35-60 y) [c]	116.8	40.8	18.2	57.9
	(70.5)	(50.9)	(32.3)	(47.9)
Age 4 (60+ y) [c]	−9.5	27.4	−14.9	−22.0
	(91.8)	(66.3)	(42.0)	(62.4)
Undergraduate student [d]	−76.4	−40.3	−1.2	−34.9
	(97.6)	(70.5)	(44.7)	(66.3)
Graduate student [d]	−56.7	−7.4	−34.2	−15.1
	(84.7)	(61.1)	(38.8)	(57.5)
Staff [d]	−107.5	−8.1	−26.7	−72.6
	(80.8)	(58.4)	(37.0)	(54.9)
Faculty [d]	−139.7	−24.5	−69.3	−45.9
	(86.9)	(62.7)	(39.8)	(59.1)
No. of observations	341	341	341	341
R^2	0.17	0.15	0.11	−0.01

Data are presented as unstandardized coefficients, with SE shown below each coefficient in parentheses.
[a] NI ranged from 0 (low) to 16 (high).
[b] Compared with grouping of patrons responding with "value recommendation" or "value price."
[c] Compared with diners who were 18 to 24 years old.
[d] Compared with "other."
** Levels of 1% statistical significance in the regression model. No variable had significance between 1% and 5% in this analysis.

Sex was the only demographic variable that had significant impact on calories purchased, with women purchasing fewer total, entrée, and side calories than men, reflecting the difference in participant body weight between sexes (79 kg and 68 kg for men and women, respectively; $P < .001$). Overweight or obese patrons tended to purchase more total calories than did normal or underweight patrons (marginally significant, $P = .06$). Although many diners responded that the signposted nutrition information influenced the healthfulness of their purchases on their surveys (Table 2), this measure was not included in the regression. A univariate regression using this variable was not significant, suggesting the variable had no effect on calories or nutrients purchased.

Regressions for protein per calorie ordered revealed that graphical signposting accounted for the major change in total protein per calories purchased and was the only variable to account for any effect. Regressions for entrée, side, and dessert protein per calories ordered did not reach significance (Supplementary Table 2). No other nutrients showed significant differences across treatments in regression analysis (data not shown). Although total saturated fat purchased significantly decreased during graphical signposting compared with the 2 other conditions, these differences were not sustained through regression modeling.

3.2.5. *Saturated fat correlations*

The decrease in saturated fat purchased during graphical signposting was partially related to the decrease in calorie purchased, as there was a significant positive correlation between grams of saturated fat and calorie ordered for all menu categories (Supplementary Table 3). To determine if the decrease in grams of saturated fat during graphical signposting was linked to the purchase of menu options containing leaner meat, the relationship between grams of saturated fat and protein per calorie was also explored. Grams of saturated fat and protein per calorie ordered showed a significant inverse relationship for all menu categories (Supplementary Table 3).

3.2.6. *Understanding of graphical signposting*

The graphical method of communicating nutrition information was well understood both subjectively and objectively without any individual instruction provided to survey respondents (Table 5). Most participants agreed or strongly agreed with the statement "I understood the nutrition graph" (83.8%). Responses to multiple choice questions requiring use of the nutrition plot reflected an even greater understanding than patrons indicated in the subjective assessment, as patrons answered with greater than 85% accuracy for all individual questions and 94.4% of respondents provided 4 or more correct

Table 5 – Survey participant understanding of graphical signposting method (n = 142)

Survey measurement	n (%)
Agreed or strongly agreed with statement "I understood the nutrition graph"	119 (83.8)
Objective understanding	Correct responses (%)
Which item is low in sodium and high in saturated fat?	123 (86.6)
Which entrée is lowest in calories?	133 (93.7)
Which food item is rated highest in protein	138 (97.2)
Which food item is rated highest in fiber?	133 (93.7)
Which food would be the best choice to combine with the Jerk Chicken [a] to create a meal balanced in the target area of fiber and protein?	136 (95.8)
Answered all 5 correctly	111 (78.2)
Answered ≥4 correctly	134 (94.4)

Data are presented as frequencies.
[a] Referred to a high-protein, low-fiber entrée from the cafeteria menu.

answers (of 5). Identifying the food on the nutrition plot that was highest in protein was the most accurately answered question (97.2% accuracy), whereas using the color-coded half circles to identify sodium and saturated fat ratings was the question answered incorrectly most often (86.6% accuracy).

4. Discussion

Our hypothesis for this work was that a visual presentation of nutrient content of foods would allow users to more effectively process information for decision making in time-constrained settings than numerical information. This hypothesis was supported by the present work. Graphically presenting nutrient information 2-dimensionally improved the ability of individuals to process and recall the information compared with numeric information. In the cafeteria study, graphical signposting effectively changed purchasing behavior toward the intended direction of reducing calories purchased without reducing protein purchased. The graphical signposting was the only significant variable that accounted for the changes in decreased calories purchased and increased protein per calories purchased after regression analysis. In contrast, consistent with other studies [8,16,26], numerical signposting had no effect on calorie purchased despite the study population being well educated, interested in nutrition information, and not having previous access to the nutrition information of the café's menu.

Fiber per calorie, the other nutrient value plotted 2-dimensionally, did not reach statistical significance in either the recall or cafeteria study. The most likely reason for the absence of an effect for graphical signposting on the total meal content of fiber per calorie in the cafeteria study is the lack of variation in fiber content of entrées offered in the menu, which most calories in a meal came from. In contrast, the lack of statistical significance in side items is likely due to (1) large variations in fiber content per calorie of side items offered on the menu (eg, daily steamed vegetable vs daily starchy vegetable offerings) and (2) a smaller number of sides purchased compared with entrees. It is also possible that information presented on the y axis of the nutrition plot is easier for users to distinguish and use than the information on the x axis as the same pattern was observed in the recall study, which showed a weaker effect in fiber plotted in the x-axis. Another possible contributor is that protein may hold greater importance to the study population than fiber, which was reflected in survey responses that showed protein being ranked higher than fiber as a nutrient of interest.

The color coding of saturated fat and sodium did not yield unequivocal results like the 2-dimensional plotting of protein per calorie. Although saturated fat purchased was significantly lower in the graphical period, the significance disappeared in regression analysis. Also, the strong correlation between saturated fat purchased and calories purchased and an inverse correlation between protein per calories purchased and saturated fat purchased, indicate that this finding is at least in part secondary to the increase in protein per calorie purchased during the graphical period. The lack of an effect on sodium purchased may be attributable to both the display format and limited variation in sodium content of menu options, as most entrées had high sodium content. The absence of a clear effect of threshold-based color coding for saturated fat and sodium in the current study is consistent with existing literature [12,13,15]. These studies suggest that although color-coding nutrient content of foods using a traffic light–style approach is most favored by consumers, it does not lead to behavior change in realistic settings when shown for more than one nutrient. A likely explanation of our findings and others is that processing information for multiple nutrients may be too overwhelming for consumers to make a decision under time constraint, particularly when ratings of multiple nutrients conflict with each other.

Two-dimensionally displaying quantitative values of 2 select nutrients along with a target representing recommendations is a promising approach to deliver nutrient information for decision making in a practical setting. Our study showed a significant improvement in protein per calorie purchased although the cause underlying the weaker effect on fiber per calorie than protein per calorie is yet to be investigated. The primary advantage of the 2-dimensional approach over other methods such as NFP, color coding, and bar graphs is its ability to position quantitative values of 2 nutrients of multiple foods in a single space. This spatial distribution of food items is likely a contributing factor to the effectiveness of the system by enabling fast and easy comparisons in the time-constrained condition of our study. Also, the emphasis of the 2-dimensional display on identifying the best choices within a selection of foods may have led consumers to react more positively to nutrition information than when simple color coding is used to identify which foods to avoid, such as in a traffic light approach.

The main strength of our study was a comprehensive study design which included 2 comparison groups, a realistic setting, collection of data before and after introduction of nutrition information, and objective measurement of purchase behavior. A recent review that focused on methodological quality of simplified nutrition information research underlined the importance of objectively measuring the impact of interpretational aids on behavior change of consumers rather than only measuring improvements in understanding of nutrition information [14]. Results of the review show that studies that objectively measure longitudinal behavioral change in a realistic setting against a control measure, such as collecting sales data before and after introduction of nutrition information, were of the highest quality and relevance. In addition, our study used questionnaires to determine self-reported usefulness and understanding of nutrition information as well as sales data to objectively determine the impact of signposting on consumer purchases.

A limitation of the study was the high education level of the study population. It is possible that individuals with a higher education level are able to more easily interpret the graphical presentation of nutrition information. However, the relevance of the results is still strong, as 43% of the study population was overweight or obese, and our regression results did not show an impact of education level on nutrients purchased. Moreover, graphical methods to visualize nutrition information seem to be more effective in low-literate populations [17], and color coding nutrient information is favored by consumers over numerical presentation [12,13]. Because our method (1) uses an intuitive 2-dimensional display, (2) displays only a few select nutrients, and (3) is easily understood without elaborate instructions, it is possible that the method is also effective in broader populations with varied education levels. An additional limitation of the study is lack of variation in fiber content of the displayed entrées. A larger variation in fiber content of food offerings would have allowed us to conclusively determine the effectiveness of plotting fiber per calorie on purchase decision.

Based on the findings and limitations of the study, future studies of this graphical method in more diverse populations with a menu containing more diverse selections in fiber are warranted. Also, studies could be conducted to determine for the effectiveness of presenting nutrient combinations other than fiber and protein for other dietary intervention needs. A potential practical use of the method upon demonstrating the efficacy in a broader population includes providing nutrient information in restaurants and possibly grocery stores to aid consumers making purchasing decision as well as recipe analysis in household settings. As encountered in our study, it is expected that not many menu items have sufficient fiber content because only 10% of the US population meet the minimum recommendation of fiber intake [27]. Nevertheless, provision of the analysis would still show the best available choices in a restaurant and could encourage restaurants to provide healthier dishes when the provision of the information affects sales. Also, the format of the plot can be adjusted for restaurants offering healthful menus to emphasize that customers can have beverages and desserts and still have a healthy meal when combined with entrées and sides with high protein and fiber instead of discouraging purchase of beverages and desserts.

In conclusion, the work has shown the efficacy of a visual presentation of nutrient information using a color-coded 2-dimensional plot in facilitating healthful consumer purchases, whereas numerical presentation was not effective. The method was well understood and effective at improving recall and promoting the desired behavior change in a realistic setting, warranting future work with the tool in more diverse settings. More broadly, the study indicates that 2-dimensionally presenting quantitative nutrition information for 2 select nutrients relative to a target is promising as an approach to make nutrient information easily and quickly usable to consumers in time constrained settings.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.nutres.2015.10.009.

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