A Computerized Social Cognitive Intervention for Nutrition Behavior: Direct and Mediated Effects on Fat, Fiber, Fruits, and Vegetables, Self-Efficacy, and Outcome Expectations Among Food Shoppers

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ABSTRACT

This study examined the direct and mediated impact of a self-administered, computer-based intervention on nutrition behavior, self-efficacy, and outcome expectations among supermarket food shoppers. The intervention, housed in kiosks in supermarkets and based on social cognitive theory, used tailored information and self-regulation strategies delivered in 15 brief weekly segments. The study sample (N = 277), stratified and randomly assigned to treatment or control, was 96% female, was 92% White, had a median annual income of about $35,000, and had a mean education of 14.78 ±2.11 years. About 12% of the sample reported incomes of $20,000 or less, and about 20% reported 12 years or fewer of education. Analysis of covariance immediately after intervention and at a 4- to 6-month follow-up found that treatment led to improved levels of fat, fiber, and fruits and vegetables. Treatment also led to higher levels of nutrition-related self-efficacy, physical outcome expectations, and social outcome expectations. Logistic regression analysis determined that the treatment group was more likely than the control group to attain goals for fat, fiber, and fruits and vegetables at posttest and to attain goals for fat at follow-up. Latent variable structural equation analysis revealed self-efficacy and physical outcome expectations mediated treatment effects on nutrition. In addition, physical outcome expectations mediated the effect of self-efficacy on nutrition outcomes. Implications for future computer-based health promotion interventions are discussed.

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INTRODUCTION

Diets high in fat and low in fiber and fruits and vegetables have been associated with increased risk for cancers, diabetes, cardiovascular diseases, other morbidities, and all-cause mortality (1,2). Although major initiatives during the last decade have resulted in some favorable dietary changes (2), only a minority of Americans reach all recommended dietary goals of 30% or fewer kilocalories (kcals) from fat, 25 g fiber per day, and 5 servings per day of fruits and vegetables (3). In addition, some purported dietary changes such as a reduction in calories from fat may be in part illusionary. For example, for the last 2 decades, the mean daily consumption of fat grams has remained at about 80 g, but caloric consumption, apparently from lower fat but higher carbohydrate, foods has increased by about 150 to 200 kcals per day (4,5). Thus, reports of reductions in percentage kcals from fat from 37% to 34% (3) may need some qualification. In addition, despite ready access by most population segments to a wide variety of healthier foods, overweight and obesity may have increased because of high-fat, high-calorie "fast," prepared, and snack foods and by foods with an emphasis on quantity, such as "super-sized" portions (4–8). Thus, a range of intervention strategies is needed to alter the nutritional and activity patterns of population segments to reduce overweight, obesity, and risk for cancer and cardiovascular and other diseases.

Self-administered computer-based interventions have the potential to influence dietary changes in large, albeit self-selected, groups of people. Computerized programs designed to assess users' health-related behaviors and provide personalized behavior change recommendations (9–14) have shown promise, but these "assessment and prescription" programs are generally designed to complement care from physicians and other health care professionals (15). Computer-based programs designed to be self-administered and that go beyond assessing behavior and prescribing remedies are beginning to emerge in the areas of AIDS risk-reduction (16), eating disorders (17), adult fitness

(18), youth nutrition and fitness (19), general health promotion (20), and adult nutrition (21,22). The development of computer-based interventions, however, must rest on a firm theoretical foundation to realize the potential for behavior change and risk reduction (23,24). The Nutrition for a Lifetime System© (NLS) is a self-administered, computer-based intervention based on social cognitive theory (24) developed through a series of small efficacy studies centered in supermarkets (22,25). Though of minimal dose, the NLS provides users with personalized information, behavioral strategies, and incentives for change as well as a vehicle for planning and receiving feedback on personal behavior change goals.

Although there is a growing consensus that intensive, individual-based interventions can be effectively evaluated by multiple, diet-recall interviews (26), such assessments often are not feasible or warranted for evaluating less intensive individual-, group-, or community-based interventions such as the NLS (26,27). Food frequency surveys have become more prevalent in assessing community- and population-based dietary behavior (26), and when collected concurrently with diet records, they have been shown to be sensitive to change associated with clinical and self-help nutrition interventions (27). However, self-report measures of health behavior and risk factors, especially when used alone, have been found to seriously underestimate risk behaviors in the general population (28). One effective way to increase the accuracy of self-reported food frequency surveys is to collect them in conjunction with perceived or real verifiable objective data (28). Previous research with the NLS found that annotated food shopping receipts, collected over a period of time, can provide an objective, sensitive measure of nutrition behavior of individual food shoppers (21,22,25). In conjunction with a database of supermarket foods developed specifically to evaluate nutritional content of food purchases (21), supermarket receipts can provide rich data regarding the nutritional status of individuals and families whose diets consist largely of foods purchased at food stores. For individuals who purchase a smaller proportion of foods at food stores, food shopping receipts are less sensitive to intervention-related dietary change (21,22,29). In light of the cost and response burden of annotating, collecting, and analyzing comprehensive samples of receipt data, food shopping receipts may be most useful as an objective measure used to corroborate self-report food frequency or diet-recall data. Our study used a system that included food shopping receipts and food frequency questionnaires. These measures—individually, together in a composite, and together in a latent-variable model—provide data to evaluate the effects of the NLS on nutrition behavior and nutritional goal attainment among a diverse group of food shoppers.

The NLS intervention provides information, behavioral strategies, and incentives to guide users to set and evaluate a series of goals regarding specific nutrition-related behaviors. Social cognitive theory suggests nutrition goal setting and self-regulation would directly improve participants' nutrition-related behavior. In addition to the direct effect of these intervention strategies, social cognitive theory suggests such interventions would increase nutrition-related self-efficacy and outcome expectations—processes that would also directly improve nutrition behavior. The direct and mediated effects of treatment should be evaluated with measurement systems designed to assess the nature and extent of the influence of constructs used to develop the intervention (24). Unfortunately, such measurement systems for less intensive individual, community-based, and large-group interventions are virtually nonexistent. Our study used measures of self-efficacy and outcome expectations shown to explain nutrition behavior among food shoppers (30) to explore the extent to which treatment effects were mediated by these social cognitive variables.

METHOD

Participants

Of 795 shoppers expressing interest in the study (i.e., returned at least some part of the enrollment packet; see the following Procedure section), 464 (58%) were recruited for the study (i.e., returned complete packets and one initial food shopping receipt). Of the recruited sample, 363 (79%) returned at least 4 weeks of food shopping receipts and were enrolled in the study. Of the enrolled sample, 67 (18%) dropped out prior to intervention. Of the 296 who participated in the intervention phase of the study, 148 were assigned to the control condition, and 148 were assigned to use the NLS kiosk. All 148 control participants completed the intervention phase and provided posttest data. Nineteen NLS participants dropped out, however, during the intervention phase (13% of NLS participants), resulting in 129 NLS participants providing posttest data (posttest $N = 277$). At follow-up, 91 control participants and 72 NLS participants provided data (59% of intervention participants, 45% of enrolled participants).

Procedure

Participants were recruited in five supermarkets using procedures consistent with store operations involving brief face-to-face contact followed by a mail back of enrollment materials (these procedures are described in detail elsewhere) (25). To enroll in the study, participants were required to complete a detailed demographic survey and to mail back at least 4 weeks of annotated food shopping receipts. After enrolling, participants continued to send baseline food shopping receipts and completed the Block95 Food Frequency Questionnaire (FFQ) (31) and the NLS Food Beliefs Survey. After baseline, enrolled participants were stratified by race, education, and family size and randomly assigned from stratification groups into the NLS treatment or the no-treatment control condition. Participants submitted food shopping receipt data throughout the intervention phase and completed FFQs and NLS Food Belief Surveys immediately after intervention. Four to 6 months after intervention, participants completed final FFQs and submitted 6 weeks of food shopping receipts.

Participants received $10 for completing enrollment forms, $10 for baseline, $15 for posttest FFQs and NLS Food Beliefs Surveys, and $20 for follow-up FFQs. Participants also received $5 per week for returning annotated food shopping receipts during baseline, $7 per week during the intervention phase, and $10 per week during the follow-up phase. Participants using the NLS program had access to coupons (see following) and redeemed a mean of $34 in coupons during intervention. Control participants received an equivalent payment at the end of intervention.

NLS Intervention

Stand-alone kiosks located in the five recruitment supermarkets housed the NLS computers. NLS users accessed the system with assigned passwords. Overall, the NLS program guided participants to decrease fat and to increase fiber, fruits, and vegetables in their food purchases and consumption. Specifically, the NLS segments focused on increasing purchases and consumption of cruciferous vegetables, fruits rich in vitamins C and A, moderate- to high-fiber bread and cereals, lowfat or nonfat dairy, and other lean protein sources. In addition, the NLS focused on decreasing purchases and consumption of discretionary fat (especially butter and margarine), high-fat ground beef, and high-fat snack foods. The NLS consisted of 15 weekly segments: 10 content segments followed immediately by 5 segments devoted to maintenance. Using pictures, graphics, and an audio track, each segment provided prescriptive information, suggested strategies for monitoring and planning food purchases and meal preparation, and provided opportunities for personalized goal setting and feedback for each targeted food group or behavior change strategy. In addition, the NLS offered targeted food coupons with the type, order, and value of coupons dependent on the program segment's content, a product's cost, and a weekly coupon allotment. The total value of the coupons available each week ranged from about $8 to $12. Coupons were printed at the kiosk, and to promote immediate use, redemption was limited to the NLS user at the kiosk store within 1 week of printing. Completion of all parts of each segment required 5 to 10 min, with longer segments providing behavior change planning and feedback. More details about the NLS program can be found elsewhere (21,25).

Measures

Nutrition outcomes. Nutrition outcomes were measured with food shopping receipts, FFQs, and a composite of the two measures. Values for percentage kcals from fat, fiber grams per 1,000 kcals purchased, and servings of fruits and vegetables per 1,000 kcals were gleaned from each measure.

This study utilized food shopping receipt data collected during the last 6 weeks of each study phase. Receipts spanned an average of 34 days for each phase of the study, 135 food items per participant at baseline, 126 items at posttest, and 140 items at follow-up. Food purchases were analyzed for fat, fiber, and fruit and vegetable content utilizing the NLS Supermarket Foods Database (SFD) (21). In general, receipted food items along with amount purchased, price paid, date and store of purchase, and participant identifiers were entered into the NLS Grocery Receipt Recording Program (GRRP). The GRRP, computer software culminating 10 years of NLS research (21,22), linked each food item through its receipt label to the NLS–SFD. The NLS–SFD contains information on grams of fat, grams of fiber, kcals, and servings of fruits and vegetable for each ounce of the purchased food. The GRRP automatically updated the NFS–SFD with new food items and receipt label links; the GRRP also automatically initiated needed updating of the NFS–SFD nutrition information. Food purchases were aggregated for study phase generating baseline, posttest, and follow-up values for total grams of fat, total grams of fiber, total kcals, and total servings of fruits and vegetables for each participant. These total phase values served as the basis for percentage of kcals from fat, grams of fiber per 1,000 kcals, and servings of fruits and vegetables per 1,000 kcals.

FFQs were collected from participants 4 weeks into baseline, at the end of posttest, and at the beginning of follow-up. Participants received instruction to report food consumption for the respective phase of the intervention. Block Dietary Data Systems (BDDS) (31) scored the FFQs and provided values for percentage of kcals from fat. Based on the scores provided by BDDS, we generated values for fiber grams per 1,000 kcals (daily fiber grams/[daily kcals/1,000]) and servings of fruits and vegetables per 1,000 kcals (daily servings of fruits + daily servings of vegetables/[daily kcals/1,000]).

For participants submitting both food shopping receipt data and FFQ data, we calculated composite (i.e., mean) nutrient values for percentage of kcals from fat, fiber grams per 1,000 kcals, and fruit and vegetable servings per 1,000 kcals at each assessment point (baseline, posttest, and follow-up). In addition to providing an outcome measure incorporating both nutrition instruments, these composites served as the basis for gauging the magnitude of nutritional change associated with the intervention and for determining nutritional goal attainment.

Social cognitive variables. The NLS Food Beliefs Survey (30) measured self-efficacy and outcome expectations 4 weeks into baseline and at the end of the intervention phase. The survey's self-efficacy questions emerged from formative work with past users of the NLS (21,22) and assessed self-efficacy for buying, preparing, eating, and serving lower fat and higher fiber foods and more fruits and vegetables. The scale prompted participants to rate their certainty in performing the behaviors "all or most of the time … for a long time … in a lot of different situations," with the scale ranging from 1 (*very sure I cannot*) to 10 (*very sure I can*). Examples of self-efficacy items included "I can bring a slice of bread with fiber to work or school for a snack" and "I can get at least 4 servings from every pound of ground beef I buy." Factor analysis of the items (30) resulted in the three self-efficacy factor-based scales (32) used in our analyses: (a) Self-Efficacy for Increasing Fiber and Fruit and Vegetables (internal consistency, $\alpha = .90$), (b) Self-Efficacy for Decreasing Fat in Snacks ($\alpha = .88$), and (c) Self-Efficacy for Decreasing Fat in Meals ($\alpha = .83$).

The NLS Food Beliefs Survey also assessed the three components of outcome expectations defined by Bandura (24)—*physical*, *social*, and *self-evaluative*. Questions on the scale asked participants to "tell us what would happen if you ate and served your family a healthy diet every day." Participants used a 5-point

Likert-type scale to rate how much they agreed that certain outcomes would result. Items included physical outcomes (e.g., "I will be hungrier," "The food I eat won't taste good,") and self-evaluative outcomes (e.g., "I will be doing what I know I should."). Social outcomes, specifically family reactions to specific nutrition-related behaviors, were measured with a Likert-type scale ranging from 1 (*My family would strongly dislike or be angry*) to 5 (*My family would strongly like or be glad*). Social outcome items included "If serve bread with fiber to my family …" and "If I serve more vegetables at meals …". Factor analysis (30) yielded four factor-based (32) outcome-expectations scales: (a) Expected Family Reactions (α = .88), (b) Expected Health Outcomes (α = .91), (c) Expected Budgetary Outcomes (α = .84), and (d) Expected Appetite Satisfaction (α = .76).

Demographic characteristics. Participants provided demographic information during study recruitment and enrollment. In addition to participant age, sex, and race or ethnic background, participants reported the highest level of education achieved by all adults in the home, the occupation of all adults in the home, the household income, and the number of children living in the home. Although age and education variables were measured in years, income was measured in categories ranging from 1 (*less than $10,000 per year*) to 10 (*greater than $90,000 per year*). Primary occupations of adults in the home reported by participants were coded based on Duncan's system (33) ranging from 0 (*no paid job or profession indicated*) to 13 (*school teacher*). Standardized values for the highest level of education of adults in the home, highest level of occupation of adults in the home, and family income contributed equally to a composite variable of household socioeconomic status (SES).

Statistical Analysis

Analysis of covariance (ANCOVA) determined treatment effects on FFQ, receipt, and composite measures of percentage of kcals from fat, fiber grams per 1,000 kcals, and fruit and vegetable servings per 1,000 kcals at post and follow-up. ANCOVA was also used to determine treatment effects on social cognitive variables (self-efficacy and outcome expectations) at posttest. Participant demographic variables (SES, age, and number of children in the home) and baseline values for the corresponding dependent variables served as covariates in these analyses.

Latent variable structural equation modeling (SEM) examined the extent to which any observed treatment effects on nutrition outcomes were mediated by treatment effects (if any) on social cognitive variables. Consistent with social cognitive theory, SEM also examined the extent to which the effect of self-efficacy on the nutritional outcomes was mediated by outcome expectations. A technique most commonly used to analyze nonexperimental data, latent-variable SEM is a preferred method for examining mediating effects within experimental studies (34). SEM controls for measurement error by incorporating multiple measures or measurement reliabilities, and it allows simultaneous testing of relevant relations (i.e., paths). Figure 1 illustrates the six models tested—models at posttest and follow-up for fat, fiber, and fruit and vegetable outcomes. SEM

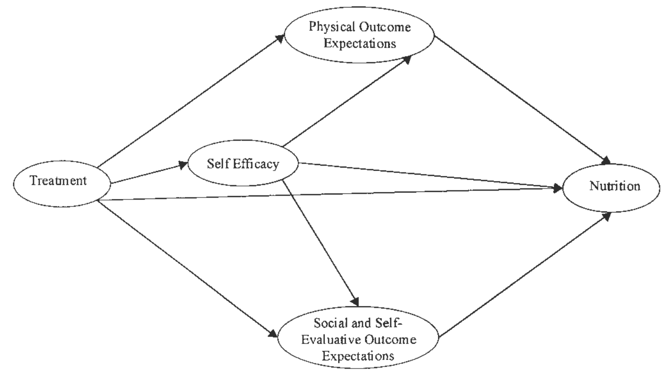

FIGURE 1 Social cognitive model of treatment effects on nutrition behavior.

allowed us to evaluate to what extent the total effects of treatment were *direct* or independent of social cognitive variables and to what extent they were *indirect* or mediated by the social cognitive variables. SEM also allowed us to evaluate how well the models fit the NLS study data: (a) goodness-of-fit index of .90 or greater, (b) adjusted goodness-of-fit index of .80 or greater, (c) normed fit index of .90 or greater, (d) root mean square error of the approximation equal to or less than .05 (α = .05), and (e) chi-square. The squared multiple correlation (R^2) associated with the latent fat, fiber, and fruit and vegetable variables allowed us to evaluate the effectiveness of the models in explaining the variance observed in the sample's nutrition behavior at post and follow-up.

Prior to conducting the SEM analysis, variables were examined for normality. Although several variables were slightly skewed, servings of fruits and vegetables and grams of fiber from food shopping receipts had severe kurtosis (kurtosis statistics ranging from 5.99 to 50.06). These variables, at posttest and follow-up, were transformed using the Log10 transformation operation in SPSS, Version 10.0 (35), resulting in normally distributed variables. LISREL software, Version 8.3 (36), then generated a covariance matrix of measures of treatment, social cognitive, and outcome variables from raw data imported (including transformed variables) from SPSS (35). The structural models used measures of nutrient values from food shopping receipts and FFQs. Self-efficacy, physical outcome expectations, and social and self-evaluative expectations variables in the model reflect those measured variables influenced by the NLS treatment (i.e., ANCOVA). Error terms for latent variables in the models with single indicators were estimated as the indicator's variance times one minus the indicator's reliability (37).

Logistic regression analysis determined the effects of treatment and social cognitive variables on nutritional goal attainment at post and follow-up. A participant was considered to have attained the goal for fat if the composite measure of fat indicated 30% or fewer kcals from fat. The fiber goal was attained if the composite measure of fiber indicated at least 25 g fiber per day (based on a 2,000-calorie-per-day diet). Last, the goal for fruits and vegetables was attained if the composite measure of fruit and vegetable servings indicated at least five servings of fruits and vegetables per day (based on a 2,000-calorie-per-day diet). Goal attainment analysis was conducted in two steps. The first step determined the effect of treatment on posttest and follow-up goal attainment controlling for demographic variables and baseline goal attainment rates. The second examined to what extent the social cognitive variables added to the prediction of goal attainment outcomes. The multivariate odds-ratios (MORs; $\alpha < .10$) resulting from the logistic regression analyses represent the relative frequency of goal attainment when the predictor variable changes by one unit: no treatment compared to treatment or 1 *SD* change in other noncategorical variables.

RESULTS

The sample participating in the NLS intervention ($n = 277$) was 96% female, was 92% White, had a median annual income of about $35,000, and had a mean of 14.78 ±2.11 years of education. About 12% of the sample reported incomes of $20,000 or less, and about 20% reported 12 years or fewer of education. Compared to participants completing intervention, participants who were recruited but did not enroll in the study ($n = 433$) were younger, had less education, had lower levels of occupational status, and had more children. Participants who did not enroll ($n = 433$) had a mean age of 42.37 ($SD = 11.86$, $p < .001$) and mean years of education of 14.37 ($SD = 1.92$, $p < .05$). Participants not enrolling in the study compared to those who completed intervention had mean Duncan-based (33) occupational levels of 8.28 ($SD = 3.40$) versus 9.25 ($SD = 3.34$, $p < .001$) and 1.13 children ($SD = 1.18$) versus 0.70 children ($SD = 1.00$, $p < .001$). The 33 participants who enrolled but did not participate in the intervention (i.e., baseline dropouts) had fewer children ($M = 0.76$, $SD = 0.74$, $p < .05$) than those who did not enroll. In addition, baseline dropouts had lower incomes than participants who did not enroll and than participants who completed intervention (mean of about $25,000 vs. mean of about $35,000, $p < .01$). Finally, baseline dropouts had lower levels of occupational status ($M = 6.44$, $SD = 3.85$) than either of the other groups (see earlier, $p < .05$).

Use of the NLS Intervention

Of the 148 participants assigned to NLS intervention condition, 129 viewed at least 3 segments of the 15-segment intervention with a mean of 10.36 segments viewed ($SD = 3.96$). Within the week of each segment's first viewing, NLS users were allowed to visit the kiosk to review content as many times as they wished. Most participants did not revisit segments ($M = 0.86$, $SD = 1.41$), but about 20% of the participants made 2 to 10 total revisits to the NLS kiosk to review 1 or more of the 15 segments. Coupons were offered to participants only once for each segment (i.e., not when revisiting program segments). Of the approximately $140 in coupons available to NLS users if they viewed every segment and selected all available coupons, NLS users selected a range of $10.15 to $127.81 in total coupons (M = $67.92, SD = $28.28). Of the coupons selected, about 45% were redeemed (M = $33.92, SD = $23.86). Small, positive correlations were observed between the composite measure of posttest fiber and coupon redemption ($r = .22$, $p < .05$) and between composite posttest servings of fruits and vegetables and kiosk revisits ($r = .23$, $p < .05$), but such correlations did not hold at follow-up. Posttest and follow-up composite measures were independent of the number of segments viewed by NLS participants (Pearson r, $\alpha = .05$).

Nutritional and Social Cognitive Outcomes

Control group and NLS user group means and standard deviations at baseline, posttest, and follow-up for the three nutritional measures are displayed in Table 1. ANCOVA at baseline indicated no between-group differences on any measure of fat, fiber, and fruit and vegetable servings controlling for participants' household SES, number of children, and age ($\alpha = .10$). At posttest, controlling for demographic characteristics and baseline fat levels, NLS users had lower levels of fat in the food shopping receipts, the FFQ, and the composite fat measure. Although the composite percentage of kcals from fat among control group participants increased slightly from baseline to posttest, among NLS users composite fat decreased by 9%. These differences were maintained at follow-up in the FFQ and composite measures but not in the food shopping receipt measure (see Table 1).

Among the covariates, only household SES influenced participants' posttest percentage of kcals from fat as measured by the food shopping receipts, $F(1, 255) = 5.986$, $p < .05$, and the composite fat measure, $F(1, 189) = 4.115$, $p < .05$. Household SES influenced fat levels neither from these measures at follow-up nor from fat as measured by the FFQ at either assessment point. Although household SES negatively correlated with fat levels from food shopping receipts ($r = -.27$, $p < .001$) and from the composite fat measure ($r = -.22$, $p < .01$), post hoc analyses of interactions between SES and treatment indicated the effects were independent ($\alpha = .10$).

In addition to lower levels of fat at posttest, NLS users had higher levels of fiber grams per 1,000 kcals (controlling for demographic and baseline fiber variables) on the food shopping receipts, on FFQs, and in the posttest composite fiber measure. Although the composite fiber grams per 1,000 kcals among control participants decreased slightly from baseline to posttest, among NLS users composite fiber increased by almost 19%. These differences were maintained at follow-up in the FFQ and composite measures but not in the food shopping receipt measure. None of the demographic covariates influenced any of the posttest or follow-up measures of fiber.

At posttest, NLS users also had higher levels of fruits and vegetable servings per 1,000 kcals in the FFQ and the composite fruit and vegetable measure but not in the food shopping receipts. Although the composite servings per 1,000 kcals among control participants remained unchanged from baseline to posttest, among NLS users composite servings increased by over 20%. These differences were maintained at follow-up. None of the demographic covariates influenced any of the posttest or follow-up measures of fruits and vegetable servings.

TABLE 1
Baseline, Posttest, and Follow-up Means and Standard Deviations for Control and NLS Users: Three Measures of Nutrient Values

	Food Shopping Receipts			*Food Frequency Questionnaires*			*Composite*		
Variable	*Control*	*NLS*	*F (df)*	*Control*	*NLS*	*F (df)*	*Control*	*NLS*	*F (df)*
Fat (% calories)									
Baseline									
M	31.67	32.78	0.860	33.64	33.49	0.035	32.74	33.24	0.240
SD	8.80	9.60	(1, 267)	7.86	7.51	(1, 254)	6.85	7.28	(1, 253)
n	148	129		137	125		137	124	
Posttest									
M	33.55	31.13	6.676***	33.25	30.37	11.167***	33.36	30.10	15.228****
SD	9.40	10.15	(1, 255)	8.33	7.51	(1, 200)	7.02	6.92	(1, 189)
n	145	121		121	87		118	79	
Follow-up									
M	31.93	30.60	1.564	34.29	31.39	5.47**	33.19	31.00	4.535**
SD	8.42	8.44	(1, 167)	7.96	6.96	(1, 158)	6.93	6.42	(1, 155)
n	100	72		93	72		90	72	
Fiber (g/1,000kcals)									
Baseline									
M	9.29	9.00	0.498	8.72	8.86	0.194	9.00	8.97	0.007
SD	3.78	3.22	(1, 267)	3.45	2.76	(1, 254)	3.32	2.57	(1, 253)
Posttest									
M	8.95	9.96	4.438**	8.97	10.87	23.487****	8.87	10.63	19.808****
SD	4.14	4.72	(1, 255)	3.70	3.08	(1, 200)	3.21	3.29	(1, 189)
n	145	121		121	87		118	78	
Follow-up									
M	9.73	10.48	1.302	8.65	10.74	20.993****	9.21	10.61	8.203***
SD	3.75	4.96	(1, 167)	3.46	3.26	(1, 158)	3.26	3.37	(1, 155)
n	100	72		93	72		90	72	
Fruit and vegetables (servings/1,000kcals)									
Baseline									
M	2.96	2.76	0.867	2.77	2.79	0.039	2.85	2.78	0.164
SD	1.86	1.35	(1, 266)	1.40	1.14	(1, 254)	1.34	1.06	(1, 252)
n	147	129		137	125		136	124	
Posttest									
M	2.75	3.08	1.571	2.89	3.52	14.436****	2.77	3.37	6.871***
SD	1.95	2.61	(1, 254)	1.46	1.31	(1, 200)	1.27	1.79	(1, 189)
n	145	121		121	87		118	79	
Follow-up									
M	3.05	3.35	1.106	2.80	3.34	5.249**	2.5	3.35	3.286*
SD	1.37	2.39	(1, 167)	1.40	1.46	(1, 158)	1.18	1.56	(1, 155)
n	100	72		93	72		90	72	

Note. Analysis of covariance (ANCOVA) analyses of between-group differences controlled for household socioeconomic status, participant age, and number of children in the home. ANCOVA analyses at posttest and follow-up also controlled for baseline outcome values. NLS = Nutrition for a Lifetime System©; kcals = kilocalories.

*$p < .10$. **$p < .05$. ***$p < .01$. ****$p < .001$.

Control group and NLS user group means and standard deviations for the measures of self-efficacy and outcome expectations at baseline and posttest are displayed in Table 2. ANCOVA analyses with demographic covariates indicated the groups were equivalent on all social cognitive measures at baseline. At posttest, NLS users had higher levels of self-efficacy for decreasing fat in meals than control participants. NLS users also had higher expectations at posttest that their families would accept healthier foods (social outcome expectations) and higher expectations that healthier foods would be satisfying (physical outcome expectations). There were no differences between study groups on other measures of posttest self-efficacy and outcome expectations. Finally, none of the demographic covariates influenced any of the posttest social cognitive variables.

Mediation of Treatment Effects and Effects of Self-Efficacy on Nutrition Outcomes

Figure 1 illustrates the hypothesized model of mediating effects of social cognitive variables influenced by treatment. In the

TABLE 2

Baseline, Post, and Follow-Up Means and Standard Deviations for Control and NLS Users: Self-Efficacy and Outcome Expectations

	Self-Efficacy								
	Low-Fat Meals			*Low-Fat Snacks*			*Fruits, Vegetables, & Fiber*		
	Control	*NLS*	*F (df)*	*Control*	*NLS*	*F (df)*	*Control*	*NLS*	*F (df)*
Baseline									
M	6.70	6.89	1.004	7.24	7.29	0.025	7.29	7.50	1.038
SD	1.79	1.82	(1, 256)	1.67	1.86	(1, 256)	1.78	1.58	(1, 256)
n	139	125		139	125		139	125	
Posttest									
M	6.68	7.01*	3.999**	7.18	7.38	0.809	7.38	7.58	0.058
SD	1.73	1.67	(1, 224)	1.61	1.80	(1, 224)	1.67	1.73	(1, 224)
n	132	98		132	98		132	98	

	Outcome Expectations											
	Appetite Satisfaction			*Budgetary Outcomes*			*Health Outcomes*			*Family Reactions*		
	Control	*NLS*	*F (df)*	*Control*	*NLS*	*F (df)*	*Control*	*NLS*	*F (df)*	*Control*	*NLS*	*F (df)*
Baseline												
M	3.92	3.97	0.024	3.39	3.40	0.101	4.29	4.37	1.462	3.15	3.17	0.010
SD	0.90	0.93	(1, 256)	1.09	1.10	(1, 256)	0.66	0.59	(1, 256)	0.79	0.75	(1, 257)
n	139	125		139	125		139	125		138	122	
Posttest												
M	3.94	4.13*	2.799*	3.40	3.39	0.292	4.32	4.40	0.225	3.16	3.31**	5.729**
SD	0.91	0.88	(1, 224)	1.07	1.14	(1, 224)	0.63	0.58	(1, 224)	0.76	0.72	(1, 224)
n	132	98		132	98		132	98		131	96	

Note. Analysis of covariance analyses of between-group differences at posttest controlled for household socioeconomic status, participant age, number of children in the home, and baseline values. NLS = Nutrition for a Lifetime System.

$^*p < .10$. $^{**}p < .05$.

model self-efficacy, physical outcome expectations and social outcome expectations mediate treatment effects on nutrition behavior. In addition, physical outcome expectations and social outcome expectations mediate the effects of self-efficacy on nutrition behavior. In the tested models, the measures of self-efficacy and outcome expectations were those found to have been influenced by the NLS treatment (i.e., ANCOVA analyses: self-efficacy for decreasing fat in meals, expectations for family reactions, and expectations for appetite satisfaction). Latent-variable SEM analysis (LISREL software, Version 8.3) (36) tested six social cognitive models of treatment effects on nutrition behavior: posttest and follow-up models each for fat, fiber, and fruit and vegetables. Table 3 contains the intervariable correlations, means, and standard deviations associated with the measured variables in the latent-variable models. Table 3 also contains the completely standardized factor loadings of latent variables on the measured variables within the models. Table 4 contains the standardized coefficients associated with the total, direct, and mediated effects of treatment and social cognitive variables on post and follow-up fat, fiber, and fruit and vegetables along with the fit statistics associated with each tested model.

SEM analysis confirmed the NLS treatment's total effects on posttest and follow-up fat, fiber, and fruit and vegetable servings. NLS users had lower fat, higher fiber, and higher fruit and vegetable levels at post and follow-up than control participants. In addition, SEM analysis confirmed the NLS's effects increasing posttest self-efficacy, physical outcome expectations, and outcome expectations. Overall, the social cognitive models of NLS treatment effects (Figure 1) provided excellent fit to the data from food shoppers, explaining from 33% to 59% of the variance observed in the latent fat, fiber, and fruit and vegetable variables at posttest and follow-up (see Table 4).

In addition to confirming treatment effects, SEM analysis revealed that the total effects of treatment on nutritional outcomes were partly direct or independent of the social cognitive variables (see Table 4). The total effects of treatment were also partly mediated, or were exerted through treatment's effects on self-efficacy and outcome-expectations variables, which then influenced nutrition behavior. Self-efficacy and physical outcome expectations mediated the total effect of treatment on fiber and fruits and vegetables at both posttest and follow-up and on fat at follow-up. Self-efficacy, alone, mediated treatment effects on fat at posttest. Social outcome expectations did not mediate the effects of NLS treatment among food shoppers. Self-efficacy exerted the strongest total effects on nutritional outcomes observed in the SEM analyses. Physical outcome expectations mediated the effects of self-efficacy on fiber at posttest and follow-up and on fat and fruit and vegetable servings at follow-up.

TABLE 3

Intervariable Correlations, Means, Standard Deviations, and Factor Loadings[a] Associated With Measured Variables Used in the Latent Variable Structural Equation Analysis: Effects of Treatment and Social Cognitive Variables on Fat, Fiber, and Fruit and Vegetable Posttest and Follow-Up

	Latent Variables and Associated (Numbered) Measured Variables															
	Treatment	*Self-Efficacy*	*Physical OE*	*Social OE*	*Post Fat*		*Fup Fat*		*Post Fiber*		*Fup Fiber*		*Post F&V Servings*		*Fup F&V Servings*	
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
	Treatment	*Low-Fat Meals*[b]	*Appetite Satisfaction*[b]	*Family Reaction*[b]	*Receipt Fat*	*FFQ Fat*	*Receipt Fat*	*FFQ Fat*	*Receipt Fiber*[c]	*FFQ Fiber*	*Receipt Fiber*[c]	*FFQ Fiber*	*Receipt Servings*[c]	*FFQ Servings*	*Receipt Servings*[c]	*FFQ Servings*
1	.89															
2	.132	.97														
3	.065	.343	.84													
4	.126	.589	.252	.89												
5	–.094	–.320	–.067	–.223	.51											
6	–.178	–.411	–.285	–.279	.342	.67										
7	–.070	–.401	–.190	–.263	.540	.345	.60									
8	–.176	–.426	–.321	–.328	.334	.702	.445	.72								
9	.120	.335	.168	.268	–.625	–.306	–.359	–.340	.60							
10	.255	.459	.331	.329	–.263	–.591	–.292	–.549	.518	.85						
11	.075	.453	.297	.312	–.382	–.296	–.535	–.396	.624	.439	.67					
12	.288	.493	.375	.359	–.313	–.482	–.380	–.670	.503	.808	.518	.78				
13	.116	.214	.140	.240	–.426	–.202	–.228	–.180	.689	.350	.460	.296	.47			
14	.211	.340	.235	.256	–.220	–.446	–.222	–.398	.432	.798	.336	.622	.355	.75		
15	.027	.348	.272	.295	–.291	–.222	–.425	–.251	.443	.340	.759	.383	.513	.350	.67	
16	.180	.419	.310	.278	–.275	–.363	–.351	–.510	.444	.698	.499	.800	.322	.740	.453	.69
M	.63	6.85	4.03	3.26	32.62	32.02	31.49	33.09	9.31	9.75	9.97	9.55	2.87	3.15	3.16	3.03
SD	.49	1.69	.90	.75	9.85	8.07	8.43	7.68	4.46	3.57	4.30	3.52	2.29	1.42	1.86	1.44

Note. OE = outcome expectations; Fup = follow-up; F&V = fruits and vegetables.
[a]The diagonal contains completely standardized factor loadings of latent variables onto measured variables resulting from the structural equation analysis. [b]Self-efficacy and outcome expectation variables measured at posttest only. [c]Correlations and factor loadings based on Log10 transformations of raw data with nontransformed means and standard deviations.

TABLE 4
Direct, Mediated, and Total Effects of NLS Treatment and Social Cognitive Variables at Posttest and Follow-Up: Standardized Path Coefficients From Structural Equation Modeling Analyses

	Dependent Variables (Posttest Coefficient/Follow-Up Coefficient)					
Independent Variables	*Self-Efficacy*	*Physical Outcome Expectations*	*Social Outcome Expectations*	*Fat (% kcals)*	*Fiber (g/1,000 kcals)*	*Fruits & Vegetables (Servings/1,000 kcals)*
Total Effects						
Treatment	.15**/.14**	.17**/.18*	.14**/.14**	–.31***/–.23**	.34****/.28***	.30***/.14*
Self-efficacy		.47****/.48****	.68****/.66****	–.69***/–.51****	.57****/.70****	.48***/.65***
Physical outcome expectations				–.08/–.17**	.19**/.22**	.13/.21**
Social outcome expectations				.03/.–03	.02/.04	.10/.11
Direct Effects						
Treatment	.15**/.14*	.10/.11	.04/.04	–.20**/–.12*	.23**/.16***	.21***/.02
Self-efficacy		.47****/.48****	.68****/.66****	–.57****/–.55***	.47***/.47****	.35**/.47***
Physical outcome expectations				–.08/–.17*	.19**/.22**	.13/.21**
Social outcome expectations				.03/.–03	.02/.04	.10/.11
Mediated Effects						
Treatment		.07**/.07*	.10**/.09*	–.11**/–.11**	.11***/.13**	.09**/.12**
Self-efficacy				–.02/–.10	.10/.20*	.13/.17*
Fit Statistics (Posttest/Follow-Up)						
GFI				.99/.99	1.00/.98	1.00/.99
AGFI				.96/.95	.98/.88	.98/.94
NFI				.98/.97	.99/.95	.99/.97
RMSEA				.03 (p = .54)/ .03(p = .52)	.00 (p = .84)/ .10 (p = .11)	.00 (p = .91)/ .05 (p = .41)
$\chi^2(4)$				4.74 (p = .32)/ 4.56 (p = .54)	2.23 (p = .69)/ 10.16 (p = .04)	1.54 (p = .82)/ 5.67 (p = .23)
R^2				.57/.49	.46/.59	.33/.47

Note. NLS = Nutrition for a Lifetime System; kcals = kilocalories; GFI = goodness-of-fit index; AGFI = adjusted goodness-of-fit index; NFI = normed fit index; RMSEA = root mean square error of the approximation.
*p < .10. **p < .05. ***p < .01. ****p < .001.

Nutritional Goal Attainment

Logistic regression analyses determined the effects of NLS treatment on participants' nutritional goal attainment at posttest and follow-up. Table 5 contains MOR statistics associated with the treatment along with their 90% confidence intervals; each analysis included participant age, number of children in the home, household SES, and baseline goal attainment as covariates. At posttest, NLS users attained 30% or fewer kcals from fat at almost four times the rate of the control group (p < .001). NLS users reached 25 grams of fiber per day and five servings of fruits and vegetables a day (based on a 2,000 kcals/day diet) at about two times the rate of control participants at posttest. At follow-up, NLS users attained fat goals at four times the rate of the control group (p < .05) but were not more likely to reach fiber and fruit and vegetable goals.

Logistic regression also determined the extent to which the social cognitive variables affected by NLS treatment contributed to posttest and follow-up goal attainment. In these analyses self-efficacy for preparing and eating low-fat meals, expectations for appetite satisfaction, and expectations for family acceptance of healthier foods along with treatment and the baseline covariates predicted goal attainment; Table 5 displays the resulting MOR statistics with their confidence intervals. Higher, posttest self-efficacy for low-fat meals contributed to higher rates of posttest and follow-up attainment of fat goals. Higher, posttest expectations for family acceptance of healthier foods contributed to higher rates of posttest and follow-up attainment of fruit and vegetable goals and posttest attainment of fiber goals. Posttest expectations of appetite satisfaction did not contribute to nutritional goal attainment.

TABLE 5
Multivariate Effects of NLS Treatment and Social Cognitive Variables[a] on Nutritional Goal Attainment Rates at Posttest and Follow-Up Among Food Shoppers

	Fat (≤ 30% kcal)		*Fiber (25+ g/Day)*		*Fruits & Vegetables (5+ Servings/Day)*	
Variable	*MOR*[b]	*90% CI*	*MOR*	*90% CI*	*MOR*	*90% CI*
Posttest						
NLS treatment versus control	3.75****	1.97–7.12	2.07*	1.01–4.25	1.81*	1.01–3.25
NLS treatment versus control	3.38**	1.73–6.60	2.10	0.98–4.50	1.62	0.86–3.05
Self-efficacy for low-fat meals	1.33*	1.03–1.73	1.05	0.78–1.41	1.12	0.90–1.41
Expect appetite satisfaction	0.96	0.65–1.43	1.10	0.68–1.76	1.24	0.87–1.76
Expect family acceptance	1.70	0.96–2.99	1.90*	1.08–3.33	1.81**	1.11–2.96
Follow-up						
NLS treatment versus control	2.26**	1.18–4.35	1.49	0.68–3.27	1.25	0.66–2.35
NLS treatment versus control	2.09*	1.02–4.24	1.40	0.61–3.21	0.95	0.46–1.93
Self-efficacy for low-fat meals	1.67**	1.24–2.26	1.23	0.88–1.70	1.27	0.99–1.63
Expect appetite satisfaction	1.38	0.88–2.15	1.85	1.01–3.39	1.34	0.91–1.96
Expect family acceptance	1.15	0.64–2.08	1.09	0.59–2.03	1.98**	1.12–3.50

Note. NLS = Nutrition for a Lifetime System; kcals = kilocalories; MOR = multivariate odds ratios; CI = confidence interval.

DISCUSSION

This test of a computerized social cognitive intervention to improve nutrition behavior found that although use of the self-administered system involved self-selected participants, diverse users of the minimal-dose program made and maintained meaningful nutritional changes when compared to no-treatment control participants. Users of the NLS decreased fat and increased fiber and fruits and vegetables and generally maintained these changes at the 4- to 6-month follow-up. The nutrition behavior of participants in the no-treatment control group, on the other hand, generally worsened over the course of the study. In addition, NLS users were more likely than control participants to meet nutritional goals immediately after treatment and were able to maintain higher fat goal attainment rates at follow-up. These changes compare well to interventions involving considerable interpersonal contact and supports (38), suggesting that the NLS represents a type of intervention that can be used to effectively alter the fat, fiber, and fruit and vegetable content of food purchases and intake.

The NLS content, based on social cognitive theory (24), provided information, behavioral strategies, and incentives to guide users to set and evaluate a series of goals regarding specific nutrition-related behaviors. Social cognitive theory suggests such planning and evaluation of goals can change behavior directly, but also by increasing participants' self-efficacy and subsequent outcome expectations—changes that would also lead to behavior change. By modeling and testing the relations among the intervention, the nutritional outcomes, and the theoretical constructs on which the intervention was based, we demonstrated not only that the NLS treatment was successful, but also how the treatment was successful. The NLS increased specific areas of participants' self-efficacy, physical outcome expectations, and social outcome expectations: self-efficacy for preparing and eating low-fat meals, expected appetite satisfaction, and expected family reactions. Further, changes in self-efficacy and outcome expectations led to improved nutrition behavior, explaining part of the total effect of the NLS treatment on nutrition behavior among food shoppers. Indeed, the social cognitive model of the NLS treatment provided a good fit to this study's outcome data and explained a substantial portion of the variance observed in fat, fiber, and fruit and vegetable (latent) variables.

These results add to a growing body of evidence suggesting that changes in self-efficacy mediate the effects of a wide range of health-related interventions (see chapter 7 of Bandura's *Self Efficacy: The Exercise of Control* [24] for a comprehensive review). In addition, these results provide evidence as to how outcome expectations operate within a health-related intervention. Recent studies have demonstrated that outcome expectations can contribute to health behaviors such as exercise and activity (39–42), smoking cessation (43,44), nutrition behavior (30,45,46), and condom use (47). Few studies, however, have investigated how outcome expectations operate within appropriately ordered, social cognitive causal models (i.e., models in which self-efficacy precedes other social cognitive variables) (24). By modeling outcome expectations as a mediator of the effects of self-efficacy and demographic variables on nutrition, Anderson, Winett, and Wojcik (30) demonstrated how and to what extent outcome expectations can contribute to nutrition behavior among food shoppers. Physical outcome expectations, and possibly social and self-evaluative outcome expectations, influenced fat, fiber, and fruit and vegetable levels directly, but they also appeared to mediate the effects of household SES, family configuration, and self-efficacy on nutrition behavior (30). Although studies examining predictors of and attempting to change health-related outcome expectations (48–50) are emerging in the literature, our study goes one step further by demonstrating how changes in outcome expectations can contribute to improvements in nutrition.

These results suggest nutrition interventions targeting efficacy beliefs and expected outcomes (yielded from an investigation and understanding of the domains and situations relevant to specific nutritional outcomes and intervention populations) are more likely to succeed. Previous research on this sample (30), for example, suggested changes in self-efficacy for decreasing fat in meals and self-efficacy for decreasing fat in snacks would improve fat, fiber, and fruit and vegetable levels among food shoppers. In addition, although the NLS treatment did not influence self-efficacy for decreasing fat in snacks, the effects of NLS treatment on self-efficacy for decreasing fat in meals clearly led to improved nutrition. Similarly, initial findings with the sample suggested that changes in expectations that healthier foods would be satisfying would improve nutrition overall and that changes in expectations that families would accept healthier foods would lead to higher levels of fruit and vegetable servings (30). The NLS treatment did influence expectations for appetite satisfaction, and these changes appeared to be especially important in maintaining dietary changes.

Although unintentional, the NLS recruitment strategies did not result in substantial numbers of participants with low nutrition-related self-efficacy or outcome expectations. Such participants arguably might have had “worse” initial nutrition-related behavior than the study group but also arguably might have needed more detailed rationales and information and preliminary guided mastery experiences prior to goal setting and evaluation activities than provided by the very brief (5–6 min) NLS content (24).

By using multiple, self-administered dietary instruments, this study demonstrated a feasible, appropriate approach for evaluating less intensive individual-, group-, or community-based interventions (26,27). Although there is a growing consensus in dietary intervention research that such multiple measures of nutrition-related behavior may be more effective in collecting accurate dietary data (26,27,28), there are few recommendations regarding how to retain the multiple-measure nature of the data during analysis. Some authors have recommended averaging nutrient values from multiple measures (26); by using a self-report measure and an objective measure of nutrition to build such a composite measure we demonstrated how this approach can be used to detect change associated with a nutrition intervention (28). Other authors have suggested analyzing multiple measures separately to determine to what extent each is sensitive to change (27)—an approach demonstrated in our FFQ and food receipt ANCOVA tests of treatment effects. Still other authors have recommended allowing more costly or cumbersome objective measures to provide the aura of verification to participants’ self-reported behavior in the hope of improving self-report accuracy (28). Latent variable structural analysis allows researchers to utilize data from multiple measures, in effect defining *nutrition-related variables* as the underlying factors that explain the pattern of correlations among multiple measures. By using SEM to explore the effects of treatment (and the other variables) on the underlying nutrition variables, we demonstrated how researchers might control for the measurement error associated with dietary data.

The challenge for future applications of the NLS and similar stand-alone, computer-based programs will be to expand access to programs to larger groups of individuals looking for help in improving their nutrition-related behaviors. In addition, future applications of computer-based self-administered programs will want to explore how and if programs situated in other settings and social contexts can be more successful in reaching people ready and less ready for change. Self-efficacy for change is increased by supportive social environments as well as by comfortable and familiar settings (24). Taking the NLS out of the supermarket and moving it to familiar, socially supportive settings may alone be enough to attract users with lower levels of self-efficacy. As larger proportions of people from diverse ethnic and SES backgrounds have Internet access at home (51), an Internet version of the NLS would immediately expand access to larger groups of users. An Internet version could also be tailored to be incorporated into more comprehensive dietary or other health behavior change programs delivered in a wide variety of supportive settings (52).

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