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The Impact of Menu Composition on School Lunch Participation and Entrée Selection in Elementary Children: A Multi-Level Model

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The Impact of Menu Composition on School Lunch Participation and Entrée Selection in Elementary Children: A Multi-Level Model

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Nearly one-third of school-aged children are overweight or obese, putting them at an increased risk for negative health consequences during childhood and as adults. Modification of the food decision environment in the school setting is one potential mechanism to impact healthy eating in youth. This dissertation uses a multi-level model to determine if changes in menu composition will maintain participation in the school lunch program and nudge children towards selecting healthier choices at lunch.

Individual lunch purchases for one school year (N=147 days) were collected from 10,134 students (grades 1-5) during August 2009-June 2010. The schools offered three entrées per day, and days were categorized according to the number of low-fat (LF) entrées offered (0, 1, 2) on a given day. Primary outcomes of interest included 1) student participation in the lunch program, and 2) selection of a LF entrée if he/she participated. Data were analyzed using separate two-level logistic hierarchical models that partitioned the variance in each outcome into one day-level predictor (number of LF entrées offered) and four child-level predictors (gender, age, ethnicity, and SES).

The final model for participation demonstrated significant main effects for student SES ($p<0.001$) and ethnicity ($p<0.001$). The predicted probability of purchase was reduced by 0.17 when a student was classified as high SES, and this effect was constant across days offering 0, 1, or 2 LF entrées. White students were less likely to purchase school lunch compared to other, black, and Hispanic children across all types of days. The predicted probability of purchase was 0.10 lower for white students and this effect was irrespective of day score. In contrast, the final model for LF selection indicated that the difference in the probability of selection was entirely attributed to the number of LF options available to the student. The predicted probability of selection was 0.15 and 0.59 on days with one and two LF entrées, respectively, and these values were similar for all types of students.

Strong support exists for the modification of the lunch menu to "nudge" children towards healthy food choice. Implications may be particularly potent for low-income and minority students.

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Chapter 1

Introduction

Childhood obesity is now recognized as one of the most prominent and aggressive public health issues in the nation, with prevalence rates more than tripling in the last 30 years. Results from the National Health and Nutrition Examination Survey (NHANES) indicate that 31.8% of children aged 2-19 years were either overweight or obese in 2011-2012, with 16.9% of these classified as obese[1]. Although the causes of childhood obesity are complex, poor diet has been recognized as a primary behavioral determinant of this disease. A recent analysis of the 2001-2004 NHANES data[2] found that dietary energy density (ED), calculated using food only, is positively associated with body weight among children aged 2–8 years. When examining children in all age groups, lean children had lower dietary ED than that of obese children ($p=0.002$), and children with low-ED diets consumed twice as many servings of fruits and vegetables (FV) as children with high-ED diets ($p<0.001$), suggesting that diet quality is an important determinant of child overweight and obesity.

School-based nutrition interventions are one strategy used by public health researchers to address food behavior in youth. Traditional school-based interventions have employed multiple component programs to impact child diet, including nutrition education curricula, changes in the National School Breakfast and Lunch Programs, a la carte food, vending machines and marketing of school foods, and family involvement components[3]. These interventions have generally been successful in increasing participants' intake of FV, high fiber foods, water, and milk, and decreasing consumption of high-fat foods and sugary beverages[4]. However, it is unclear as to whether these programs can maintain changes in child eating behavior long-term. For example, studies of longer duration (e.g. 2 years) have demonstrated positive changes in the early stages of intervention, with no significant changes in school-based eating observed at the conclusion of the program[4,5]. In addition, schools are unlikely to have adequate resources and administrative support to sustain such programs across multiple cohorts of individuals.

New cafeteria-based research has focused on the principles of behavioral economic theory to change what and how children eat. The typical individual makes up to 200 food decisions per day[6]; therefore, interventions that focus on manipulating the food environment in a way that biases these instinctive actions towards healthy choices can have a potent effect and is sustainable for longer durations than multi-component interventions. For example, middle schools that provided pre-sliced apples to children in the lunch line, rather than the whole fruit, increased apples sales by 71% compared to control schools[7]. Likewise, changing a single lunch line in a high school cafeteria to offer only healthy foods, while continuing to offer traditional items in the second lunch line, increased the number of healthier foods students selected by 18.8%[8]. These results suggest that making healthier foods more convenient, while maintaining child autonomy in food choice, is a promising strategy to influence and maintain dietary behavior change in youth.

Therefore, this dissertation is designed to examine if small changes in the school food environment that drive youth towards healthier foods can impact child food choice, while also maintaining participation in the school lunch program. The specific aims of the current proposal are to:

1. Study One

a. Examine the extent to which natural variations in school lunch menu composition impact participation rates in the school lunch program.
b. Examine the extent to which these menu variations impact the selection of low-fat (LF) foods across schools.
c. Determine if these relationships are moderated by school socioeconomic status (SES) when aggregated at the school level.

2. Study Two
    a. Examine the extent to which the number of LF entrées offered on a given day predict the variation in individual student school lunch participation over time.
    b. Examine the extent to which the number of LF entrées offered on a given day predict the variation in individual student selection of a LF entrée over time.
    c. Examine the extent to which student gender, SES, age, and ethnicity predict the variation in individual student school lunch participation over time.
    d. Examine the extent to which student gender, SES, age, and ethnicity predict the variation in individual student LF entrée selection over time.

Delimitations

Data for this study were collected in 1st-5th graders in one school district in Central Texas. Therefore, the results of this study are delimited to children who fall within this age range. Although a large number of individual elementary schools were included in the study design (n=17), the district utilized a central kitchen to provide meals district-wide. As a result these data may not generalize to all elementary school districts – particularly those with on-sight kitchens. However, it should be noted that the schools included in this study were of varying SES and included students of a diverse ethnic makeup.

Limitations

The results of the current dissertation should be interpreted with the awareness of several limitations. First, study one measured selection and not consumption of the LF, moderate-fat (MF), and high-fat (HF) entrées. Thus, it is unclear if children were actually consuming the healthier foods purchased. Although it would have been ideal to support selection data with plate waste data, this method was beyond the scope of this study. Second, the healthfulness of school meals in this study was determined using dietary fat as the guideline, rather than nutrient density, added sugars, total servings of FV in the entrées, etc. – all of which represent reasonable approaches. New USDA meal pattern regulations, released in 2012[9], do focus on overall nutritional quality (increased FV offerings, whole grains, low-fat milk, and limiting trans-fat), rather than total fat standards. However, the aim of this study was to demonstrate that changes in menu composition can drive student choice towards healthy foods. Thus the results are applicable to other changes, e.g. added sugars in school meals, including those outlined by the USDA guidelines. Third, individual characteristics of the menu are not accounted for in these analyses. For example, it may be that an individual student did not select a LF entrée for lunch because the LF entrée is a cold entrée (e.g. salad or sandwich) and the child prefers hot entrées for lunch. Although this concern should be noted, these effects are likely to be randomly distributed across the large sample of children and are not expected to bias the results. Likewise, the wide range of foods across all fat categories of foods also serve to reduce the impact of any unaccounted, individual factor.

Definition of Key Terms

- **Body Mass Index (BMI)** – an indicator of body fatness, based on an individual's height and weight. It is defined in the units of kg/m^2 and is used to determine weight status.

- **Behavioral Economic Theory** - Individuals allocate limited resources (e.g. money or time) to obtain access to certain commodities (e.g. food) within a system of constraints (availability, price, behavioral response).
- **Competitive Foods** - foods sold outside of the formal meal programs and available as a la carté items in vending machines, snack bars, and fundraisers.
- **Coordinated Approach To Child Health (CATCH) -** an evidence-based school health program designed to increase healthy eating and physical activity, and to decrease tobacco use among elementary and middle school children.
- **Day Score** – The ISD offers three entrées available for purchase each day. Therefore, there exists 10 possible combinations of LF-HF mixes: 1) LF, LF, LF, 2) MF, LF, LF, 3) HF, LF, LF, 4) MF, MF, LF, 5) HF, MF, LF, 6) MF, MF, MF, 7) MF, MF, HF, 8) LF, HF, HF, 9) MF, HF, HF, and 10) HF, HF, HF. Using these groupings, days were coded and categorized according to the number of LF entrées offered (0, 1, 2) on a given day.
- **GO, SLOW, WHOA Foods** – The school district participates in the CATCH program and the menu items are designated as "go" (e.g. turkey sandwich on wheat, chef salad), "slow" (e.g. spaghetti and meat sauce, toasted cheese sandwich), and "whoa" (e.g. pepperoni pizza, cheese nachos) foods, indicated by green, yellow, and red dots, respectively, on the monthly calendar menu.
- **Low-fat, moderate fat, and high-fat foods** - Entrées were coded as low-fat (LF) (≤ 30% of calories from fat), moderate-fat (MF) (30 – 34.9% calories from fat), and high-fat (HF) (≥ 35% calories from fat), to align with USDA nutritional recommendations. Therefore, not all LF entrées correspond to a green food or MF entrées to a yellow food, etc. on the ISD menu.

- **National School Lunch Program (NSLP)** – Federally sponsored nutrition program that aims to provide nutritious foods to school-age children at no, or reduced, cost. Eligibility for free NSLP lunches is limited to families whose incomes are at or below 135 percent of the poverty line.
- **Overweight/Obesity** – For children and adolescents aged 2-19 years, overweight is defined as a BMI at or above the 85th percentile and lower than the 95th percentile. Obesity is defined as a BMI at or above the 95th percentile for children of the same age and sex.
- **Participation** – Did the child participate in the school lunch program that day? (1=Yes, 0=No).
- **Selection** – Given that the child participated in the school lunch program that day, did he or she select a LF entrée for lunch? (1=Yes, 0=No).

Chapter 2: Review of the Literature

Significance

National nutrition surveillance data suggest that children's diets do not meet guidelines set forth by the US Department of Agriculture (USDA). In particular, children consume excessive amounts of total fat, saturated fat, and added sugars and inadequate amounts of FV, whole grains, and essential vitamins[10-13]. Data from a recent NHANES analysis[10] indicated that the top sources of energy for US children aged 2-18 years were grain desserts, pizza, and soda. In addition, it is estimated that only 10-14% of girls and boys aged 4-8 and 18-20% of children 9-13 consume the USDA MyPyramid recommendations of five or more servings of fruits and vegetables per day[14].

Disparities in Child Diet

A negative association between diet quality and socioeconomic status (SES) has been well documented in US adults[15]. Studies examining this relationship in children have provided strong evidence for a similar pattern. A review by Hanson and Chen[16] identified 31 studies that examined the relationship between SES and adolescent dietary behavior. Of these 31 studies, 25 reported negative associations between SES background and diet; low-income children and adolescents were more likely to consume diets low in FV and higher in fat content and refined sugars and less likely to take a vitamin supplement than higher income peers. For example, Xie and colleagues[17] found that adolescents' intakes of total fat, saturated fat, monounsaturated fat, and cholesterol decreased as parent education levels increased ($p < 0.05$). In addition, subjects from families with parents who had higher educational attainment were more likely to meet the national recommendations for dairy products and FV. This is consistent with data from the third NHANES study in US adults[18]; individuals who completed only grade school consumed 1.19 daily fewer servings of FV than did those who received education beyond high school ($p<0.001$); and persons in poor families consumed 0.62 fewer daily servings than did those in high-income families ($p<0.001$). In addition, the authors noted that a one standard deviation increase in neighborhood SES index was associated with consumption of an additional 0.24 daily servings of fruit and vegetables combined ($p<0.001$).

Some differences in diet quality by gender, age, and ethnicity have been documented. A review of the determinants of child FV consumption by Rasmussen and colleagues[19] found moderate evidence for an effect of gender on FV intake, with girls more likely to consume higher intakes of FV than boys. However the majority of these differences were observed in European studies. The authors noted a small trend for decreasing FV intake with increasing age, although findings were not consistent across studies and few studies have been conducted. A longitudinal study by Lytle and colleagues[20] examined food choice in children from 3rd-8th grade using 24-hour dietary recalls collected in grades three, five, and eight. Results indicated that as children moved from elementary to middle school and junior high their consumption of breakfast, fruits, vegetables, and milk decreased, while soft drink consumption increased. A subsequent study by Cooke and Wardle[21] examined the developmental pattern of food preferences in a large sample of children aged 4-16. The authors found significant age-related differences in preferences for fruits, sugary/fatty foods, dairy, and fish. Specifically, children's preference for fruits and sugary/fatty foods reached a peak at 8– 11 years of age, while liking for fish and dairy foods was highest among the youngest children and declined with increasing age.

The association between ethnicity and dietary behavior in children has been less well studied. Analysis of data from the third NHANES found that the percentage of total energy from fat was significantly higher for black and Mexican American girls and black boys than for white girls and boys[22]. Likewise, data from the Hispanic Health And Nutrition Examination Survey (HHANES) indicated that Mexican-American children have low intakes of FV compared to white children[23]. A more recent study by Erinosho[24] et al. assessed the dietary intake of pre-school children aged three to five years using data from the 2007 California Health Interview Survey (CHIS). In congruence with previous literature, children of Hispanic caregivers consumed fewer servings of vegetables than did the children of non-Hispanic white caregivers.

Disparities in Texas

Research within the state of Texas specifically, has demonstrated differences in the health status and dietary outcomes of elementary children by race/ethnicity and sociodemographic factors. Hispanic children in Texas are more likely to live in areas with poor access to healthy foods and limited green space than their white counterparts, putting them at an increased risk for obesity and overweight[25]. Recent surveillance data from the School Physical Activity and Nutrition (SPAN) Project[26] indicated that Hispanic children (4th grade) had the greatest proportion of those who were obese (30.3%) and overweight (21.0%) ($p<.001$), compared to non-Hispanic black children (24.9% obese and 19.6% overweight) and non-Hispanic white children (14.2% obese and 12.7% overweight). Both Black and Hispanic children lived in areas with significantly higher county-level percent unemployment (Black -

8.7%, Hispanic - 9.1%, White - 7.7%) ($p<.001$), and Hispanic children had significantly lower county-level median household incomes ($41,125.22) than white children ($45,876.82) ($p<.001$). In addition, measures of social stress (e.g. percent child poverty, teen birth rate, commute time, grandparent performing parental role) were significantly higher for Hispanic and Black children than white children. Therefore, it may be particularly important to consider sociodemographic factors in examining dietary behavior in Texas children.

Health Outcomes Related to Child Diet

Poor diet is recognized as a significant risk factor for a number of chronic diseases and negative health outcomes, including: obesity[27], cancer[28], cardiovascular disease[29,30], poor bone health[31], and hypertension[32]. A number of researchers have demonstrated a direct link between overall diet quality and child weight status[33-35], with children who consume diets high in FV exhibiting lower body weights and a healthier body composition than children with diets low in these foods[36-38]. Dietary factors have been estimated to account for 30% of cancers in Western countrie [39]. Epidemiological evidence provides strong support for the consumption of fruits, vegetables, and whole grains for certain types of cancer prevention[40,41]. For example, it is estimated that an individual's increase of dietary fiber to 20 grams a day from average current intakes would reduce the rate of colorectal cancer by 40 percent[40]. In addition, it is well known that dietary patterns developed during childhood track into adolescence and adulthood[42-44], putting these individuals at risk for the development of negative health outcomes later in life. Because children consume a substantial proportion (up to 50%) of their total daily calories at school[45], the school food environment is an ideal setting to impact child eating behavior and weight status.

School-based Nutrition Interventions

Past nutrition intervention research has focused on individual behavior change [46]. In recent years, more attention has been given to broader environmental and policy change programs aimed at improving food choices for the whole student population[47,48]. Environmental change strategies within the school context typically include changes in food availability (e.g. access to healthy foods), changes in nutrition guidelines (e.g. school meal standards), changes in price (e.g. healthy items cost less), or changes in promotion, advertising, or point-of-purchase information (e.g. signs or low-fat labels)[47,48]. In addition, school-based nutrition interventions can be multi-component or stand alone and may target both healthy (increased FV consumption) and/or unhealthy (decreased consumption of high fat foods or sugar-sweetened beverages) eating behaviors[48].

A recent review by Roseman, Riddell, and Haynes[3] identified 26 school-based nutrition interventions (K-12th grade) conducted in the United States between 2000-2008. The authors performed a comprehensive content analysis and found that 54% of the programs sought to impact healthy eating in youth through changes in the school food environment. Interventions targeted the NSLP, a la carte food, vending machines, school stores, and marketing/advertising to lower the fat content of foods offered and to increase the availability of FV and whole grains. Of these 26 studies, 17 targeted elementary-aged children, with seven of these employing a cafeteria-based intervention component. Of these seven studies, two were multi-component, combined diet and physical activity intervention [49,50], three were multi-component diet only intervention[51-53], and two were environmental-only nutrition interventions[54,55]. An overview of the studies using a cafeteria-based intervention component is presented below.

Multi-component, Combined Diet and Physical Activity Interventions

Pathways[49] was a randomized, controlled school-based obesity intervention conducted in 41 schools over three years in 3rd-5th grade American Indian children. The intervention aimed to reduce the body fat of participating children through four components: 1) changing dietary intake, 2) increasing physical activity, 3) educating children about healthy lifestyles, and 4) involving the family. The nutrition component of the program sought to reduce the percent energy of fat for foods offered at school lunch to ≤ 30% and also provided skill-building techniques for food service staff to use in planning, purchasing, and preparing lower-fat meals. The 24-hour dietary recall at the end of the study showed a significantly lower total daily energy intake in the intervention group (150 kcal/day) than in the control group, although no significant changes in weight or adiposity were observed in the intervention students.

The Wise Mind pilot project[50] was a field study designed to test whether an environmental approach for weight gain prevention (Healthy Eating and Exercise, HEE), delivered in schools (2nd-6th grades), was more effective than an active control program (Alcohol/Drug/Tobacco Prevention, ADT) that used an environmental approach to prevent substance use. The nutrition components of the HEE program aimed to change school meals to meet USDA recommendations. Research staff worked with cafeteria personnel to encourage appropriate portion sizes, calories, and nutrient content of school lunches. In addition, posters, handouts, and display items in the classroom and cafeteria promoted the nutrition goals of the program. Results showed that after 18 months of intervention, participants in the HEE treatment arm were consuming fewer total calories and lower percentages of calories from total dietary fat, saturated fat, and protein than children in the

ADT treatment. Researchers used digital photography to measure food selections, plate waste, and food intake at three lunch meals for each participant. No significant differences in weight gain prevention (as measured by child BMI) were found between the two interventions.

Multi-component Diet Only Interventions

The Power 3: Get Healthy with Whole Grains pilot intervention[52] was a school-based nutrition intervention designed to increase the consumption of whole grains in 4th-5th grade children. The program consisted of a five-lesson classroom curriculum based on the Social Cognitive Theory, school cafeteria menu modifications to increase the availability of whole-grain foods and family-oriented activities. The educational component of the intervention consisted of 45-minute lessons taught each week to children enrolled in the study. The lessons were directed at improving child knowledge related to whole-grain foods, enhancing self-efficacy for these foods, building menu-planning skills and included samplings of whole-grain products. The cafeteria component focused on menu modifications that increased the availability of whole-grain foods served at school and targeted foods such as pizza, pasta, tortillas and buns. The family component included weekly parent news-letters, bakery and grocery store tours, and a "Whole Grain Day" event. Results showed a significant increase in the availability of whole grains served at intervention schools compared to control schools at post-intervention. Children in intervention schools consumed significantly more fiber and iron at post-intervention compared to children in control schools. In addition, the self-reported intake of refined grains of children in the intervention schools significantly decreased compared to parents in the control schools. The intervention did not produce significant changes in child food choice, availability and self-efficacy related to whole-grains.

The School Nutrition Policy Initiative (SNPI)[53] was a multi-component nutrition intervention conducted in 10 schools in kinder through 8th grade. The program was developed and delivered by The Food Trust, a community-based organization funded by the USDA, and included five components: 1) school self-assessment, 2) nutrition education, 3) nutrition policy, 4) social marketing, and 5) parent outreach. The nutrition education component was integrated into classroom subjects and included activities such as using food labels to practice fractions and writing assignments focused on nutrition topics. In each of the intervention schools, all of the foods sold and served were changed to meet the Dietary Guidelines for Americans; specifically, beverages were limited to 100% juice (recommended 6-oz serving size), water, and low-fat milk (recommended 8-oz serving size). Snack standards allowed seven grams of total fat, two grams of saturated fat, 360 milligrams of sodium, and 15 grams of sugar per serving. Prior to the intervention, soda, chips, and other drinks and snacks had been sold in vending machines and a la carte in the cafeteria of schools. Both social marketing techniques (raffles, role modeling with healthy characters) and family outreach components were also included in the intervention. Students in both intervention and control schools showed similar decreases in self-reported consumption of energy, fat, and FV at post-intervention, although fewer children in the intervention schools became overweight than in the control schools across the two-year program.

High 5[56] was a randomized, controlled school-based nutrition intervention program designed to increase FV consumption among 4th graders in 28 elementary schools. The intervention included a classroom component, a food service component, and a parent component. The classroom curricula was taught two times per week during the 4th grade and included: a review of information from earlier lessons, the High 5 Cheer to encode key concepts, a new "Freggie" fact, and a learning activity section to build skills, self efficacy, and outcome expectancies related to food choice. Food service managers and workers received a half- day of training on purchasing, preparing, and promoting FV that met High 5 guidelines. In addition, cafeterias were rated each month based on their completion of 10 intervention activities (e.g., offering at least 10 fruit and vegetable servings per week). Parents received an overview of High 5 during a kick-off night held at each school at the beginning of the intervention and were asked to encourage and support behavior change in the children. Measures were completed at baseline, the end of 4th grade (follow-up one), and at the end of 5th grade (follow-up two). At both follow-up one and two, the intervention children consumed significantly more servings of FV combined than control children (24-hour recall). At follow-up one, intervention parents consumed more servings of FV combined than control parents; this was not significant at follow-up two. Treatment differences were found for outcome expectancies, self- efficacy, knowledge, and social norms favoring the intervention condition for both students and parents.

Environmental-only Nutrition Interventions

The Cafeteria Power Plus Program[54] was a cafeteria-based intervention program that aimed to increase FV consumption in 1st-3rd graders over two years in 13 randomly assigned intervention schools. Intervention components included additional servings of FV that were offered at school lunch (samplings occurred each month), role modeling (flyers of life-size FV characters), and increased social support (food service staff, parent volunteers). Significantly higher intakes of FV (without potatoes, p=0.03) and fruits (without juice, p=0.00) were found among intervention students compared to control students. Specifically, intervention students consumed on average, 0.14-0.17 more servings of FV at lunch than students in the control schools. Thus, environmental interventions alone do have the potential to change child healthy eating behavior, although the magnitude of this increase was less than that observed in multi-component interventions (0.2 – 0.6 servings per day)[48].

Shape up Somerville[57] was a food service intervention that introduced a variety of low-fat, high-fiber foods, specifically bean (legume) dishes at school lunch and aimed to promote their consumption using a series of messages played daily over the PA system in six elementary schools. Schools were pair matched based on size, racial/ethnic makeup, and percentage of students receiving free or reduced school lunch. One school from each pair was randomly selected to receive the audio messages and all schools offered two new bean dishes at the same frequency over the course of one academic year. When data were analyzed for all school pairs, children in schools where the messages were played were not significantly more likely to choose beans at school lunch than children in control schools. However, when pairs were analyzed separately, a dose-response effect emerged, in that schools receiving the highest dose (daily audio message) were 2.5 more times more likely to choose a bean dish for lunch than children in the control school. Interestingly, selecting a bean dish at school lunch did not increase over time as a result of an increased exposure to the dishes, as no change in consumption occurred over time in the control schools.

Summary

Taken together, the results of these studies do provide evidence of favorable behavior change following the implementation of a school-based nutrition intervention. The multi-component interventions were successful in lowering child energy intake and percent intake from fat, and improving intrapersonal constructs related to healthy eating among youth. However, the resources needed to produce these changes are extensive and difficult to sustain long-term in a public school setting. Therefore, it is important to test the effectiveness of interventions that require minimal invasiveness, but are adequate to produce behavior change.

Behavioral Choice Theory and Food Reinforcement

New cafeteria-based research has focused on the idea of "choice architecture" and behavioral economic theory in an attempt to influence students' decisions around healthy eating. Behavioral choice theory states that individuals allocate limited resources (e.g. money or time) to obtain access to certain commodities (e.g. food) within a system of constraints (availability, price, behavioral response)[58]. Therefore, individual choice to select a healthy food item is driven in part by the effort required to obtain this commodity.

Behavioral choice theory has been paired with food reinforcement to explain how people make food decisions and to understand factors related to obesity. A reinforcer is defined as a stimulus that increases the rate of a behavior that it follows[59]. Primary reinforcers do not require prior learning and are biologically pre-established to increase behavior (e.g. food when you are physiologically hungry). Secondary reinforcers are conditioned, meaning that motivation to consume these increases in strength over time (e.g. drug addiction). The reinforcing value of food refers to the motivation to obtain food – e.g. how hard someone will work, or how much time they will allocate to obtain food[58]. There is a large body of literature that seeks to explain how reinforcement and schedules of reinforcement influence maladaptive behaviors, such as drug abuse[60,61] and gambling[62,63]. More recently these theories have been applied to individual food choice and energy balance in an attempt to explain factors that contribute to obesity.

Substitutes and Complements of Reinforcers

The behavioral choice paradigm proposes that commodities can act as substitutes for each other, as complements, or can be unrelated[58]. For example, a turkey burger can act as a substitute for a hamburger. An individual may typically purchase a hamburger for lunch at work, but if the price of the hamburger has increased in relation to the turkey burger, or if hamburgers are not available for purchase that day, a turkey burger may be an acceptable substitute for that particular meal. Complements are foods or behaviors that can be paired together (e.g. mayonnaise on a hamburger)[58]. If the price of tacos increases, consumption of guacamole may decrease as a result. The cost associated with a given behavior can be tested by varying the access or constraint associated with behavior A, while holding the constraint on behavior B constant. For example, if the cost associated with purchasing mayonnaise on a hamburger increases, but that of purchasing mustard stays the same, individuals may shift choice from mayonnaise to mustard. In this situation, mustard would act as a substitute for mayonnaise.

Goldfield and Epstein[64] investigated how increasing the "cost" of snack foods would influence choice of these foods in relation to alternative reinforcers, such as FV and non-food alternatives in a sample of young college students. Reinforcement schedules for snack foods, healthy foods (FV), and sedentary activities (e.g. video games or TV) were manipulated by the experimenters using a computer task in which participants earned points to gain access to one of the three reinforcers. The points required to obtain a snack food were progressively increased across time, while the points required for the alternatives remained constant. Results indicated a shift in choice from highly palatable, energy-dense foods to healthy foods and non-food alternatives when the response requirements to earn a point for a snack food increased. There were no significant differences in the response required for either alternative. These findings suggest that decreasing access to a less healthy reinforcer, while providing easy access to alternative reinforcers is a plausible way to create behavior change.

Delay of Gratification

The ability to engage in goal-directed activities, to plan, and to achieve later outcomes is known as delay of gratification[58]. The paradigm centers on the idea that individuals prefer smaller, immediate rewards over larger, but delayed ones. Research has indicated individual differences in the delay of gratification for food, specifically for obese versus non-obese youth. For example, Bonato and Boland[65] demonstrated that obese children were more likely to choose immediate rewards than normal weight children, but only when the incentive was edible. Recent research has demonstrated that the inability to delay gratification predicts weight gain in young children. Francis and Susman[66] measured self-regulatory capacity and delay of gratification in children aged 3-5 years. Children who exhibited low self-regulation in both procedures had significantly higher BMI *z*-scores at all time points (3, 5, 7, 9, 11, and 12 years), compared with children classified as high in both procedures. Likewise, Seeyave and colleagues[67] demonstrated that low ability to delay gratification at four years of age significantly predicted overweight at age 11.

The relationship between reinforcing efficacy, delay discounting, and behavioral choice may have significant implications for obesity. A low ability to self-regulate paired with a food environment that is focused on convenience and "fast" food choices may be particularly detrimental for overweight individuals. By understanding factors that alter choice among youth, public health researchers can modify the food environment to shift behavior towards healthy alternatives and away from high energy density foods.

Behavioral Economics and Cafeteria-based Research

Hanks and colleagues[8] examined the application of behavior choice theory in a sample of high school students by introducing a cafeteria line at school lunch that offered only healthier options. Prior to the intervention, both lunch lines available to students offered the same food items: chicken patties, sub sandwiches, tacos, hamburgers, salad, whole fruit, fruit parfait, flavored milk (chocolate or strawberry), white milk (skim, 1 or 2%), a vegetable choice and one dessert option. During an eight-week intervention period, the researchers changed one line to offer only healthier options: sub sandwich bar, salad bar, vegetables, whole fruit, fruit parfait, and flavored milk. The other line continued to offer the standard options. Consumption was measured using plate waste during four observation periods. Results indicated that during the intervention period, the number of healthier foods students selected significantly increased by 18.8%, although the percentage of these foods actually consumed was not significantly different during the intervention period. However, the consumption of less healthy foods dropped by 27.9%, suggesting that the convenience line did influence the overall mix of items consumed.

Olstad and colleagues[68] examined the use of "nudging" to cue healthier food choices in a Canadian recreation center. Specifically the researchers used three strategies to influence food choice in both adults and children during the intervention period: signs that advertised healthy items, taste-testing of healthy items, and a 30% price reduction in healthy items. Results from the full sample of participants did not show a significant increase in the sales of healthy items between the three intervention periods. However, when the results from a subsample (participants whose purchases were directly observed) were analyzed, the researchers found that the sales of healthy items increased by 30% during the signage plus taste testing intervention period. In addition, when the results were stratified by age (child, adult, child+adult), there was a 20% increase in the proportion of healthy items purchased by children only during the signage plus taste-testing period. This increase was greater than that observed for adults only or for an adult with a child, suggesting that children may be more sensitive to certain types of "nudging."

Hakim and Meissen[69] extended this research to elementary aged children. The "Choices" cafeteria intervention was designed to increase the consumption of FV among low-SES elementary and middle school students participating in the NSLP. During the intervention period, students were given the ability to choose the fruit or vegetable that they wanted for lunch from three available options. Only one category (fruit or vegetable) was designated as the "choice" option for that day; in addition, students were served a standard "non-choice" side, entrée, and milk. Consumption was measured by observing and weighing student plate waste over two 10-day periods pre-intervention and during implementation. Results indicated that during the intervention ("choice") period an average daily increase of 15% of fruits and 15.6% of vegetables was observed as part of the NSLP.

Likewise, a recent study by Wansink and colleagues[7] examined the behavioral economics theory of convenience by offering pre-sliced fruit in middle school cafeterias. Lunchroom staff at treatment schools were given apple slicers and told to pre-slice the fruit into six symmetric pieces prior to serving at school lunch. Apple sales measures and consumption data were taken using tray waste measures. Schools with fruit slicers increased average daily apple sales by 71% compared to control schools ($p<0.01$), suggesting that students who already bought apples bought them more often or students who did not buy apples started buying them. In addition, tray waste examination indicated that the percentage of students that wasted half or more of the fruit decreased by 48% (p=0.03).

These findings suggest that setting up a bound choice for children and/or making healthy foods more convenient is one way to influence the selection and consumption of these foods. Previous research has demonstrated that healthier entrées are palatable to children[70]. However, when offered alongside multiple higher-fat options (e.g. hamburger or pizza), selection of these entrées is insufficient to impact children's diets[71]. Given the results reported by Hakim and Meissen and Wansink, it is reasonable to assume that children would be more likely to select a healthy meal for school lunch if a) given an active role in the decision making process and b) provided increased access to these foods relative to competing, less healthy options.

Resistance to School Meal Changes

One challenge to modifying the food environment is resistance from key stakeholders[72]. This is especially true in school settings in which food service is managed by an outside contractor, including food service managers, who are charged with maintaining profitability through high participation rates in the school lunch program. An intervention will not be long supported if a shift to healthier entrées results in lower participation rates and less profitability for the food service management company. Lucarelli and colleagues[73] interviewed elementary school administrators and food service directors to identify barriers and facilitators to healthy eating in schools. Results from the thematic analyses indicated that one of the primary concerns among food service directors was the budget allotted for healthier items. Specifically, fresh FV and whole grains are more expensive to integrate into the menu; with the higher cost associated with these items and the possibility of reduced meal purchasing if students do not like the healthier foods, directors are reluctant to make changes. Given its importance as an outcome, it is surprising that few, if any studies have reported the impact on participation rates and, by extension, the profitability of the school lunch program. The interventions that can create a healthy shift in behavior, while maintaining or increasing student participation rates, are most likely to be disseminated and sustained over time by the food service staff that will be required for implementation.

Future Directions and Current Study

The results of this review suggest that school-based nutrition interventions can be effective in impacting dietary behavior in children. This is well documented in multi-component interventions and is demonstrated in recent cafeteria-based interventions that modify the school environment to make healthy foods more convenient and available. These studies are limited, however, in their ability to maintain behavior change long-term; few schools have the resources or are willing to continue to implement changes within the school food environment post-intervention.

One alternative approach to changing children's eating behavior is to set up the food environment so that a child's instinctive decisions about food are biased toward the healthier options. Dr. Wansink of Cornell University posits that healthy foods must be made convenient, attractive, and normative (CAN) to effectively change child-eating behavior[74]. For example, his research has shown that simply putting white milk in the front of a cooler, selling it in a pretty bottle, and giving it 50% of the total space in the cooler (compared to chocolate milk) increased sales of white milk by 38% in a sample of middle school children[74]. These changes are minimally invasive, low-cost, and sustainable in US elementary public schools across the U.S.

This dissertation is designed to expand the current literature on cafeteria choice architecture and behavioral economic theory through a secondary data analysis of lunch purchases during the 2009-2010 school year for over 10,000 children in 17 elementary schools. Study one examines the extent to which natural variations in school lunch menu composition impact both the selection of LF foods and student participation rates. Data were aggregated at the school level (N=17). Each school in the district offered three entrées per day, and days were coded and categorized according to number of LF entrées offered (0, 1, 2) on a given day. Schools were also categorized by their average SES through a frequency analysis of students on free/reduced lunch. The methods and results of this study are presented in chapter three. Study two seeks to explain the variation over time in these outcomes through the use of individual level predictors, including child SES, ethnicity, gender, and age. In order to accomplish this, separate, two-level hierarchical linear models with a binary outcome were used. The methods and results of this study are presented in chapter four.

Chapter 3: Study One: The effect of school lunch menu composition on low-fat food selection and participation rates in elementary children

Abstract

Background: Children consume a substantial proportion of their caloric intake at school, making this an ideal setting to impact child eating and weight status. While there have been concerns from food service vendors that a healthier menu will lead to lower participation rates, this has not been well tested.

Purpose: This paper examines the extent to which natural variations in school lunch menu composition impact both the selection of low-fat (LF) foods and student participation rates.

Methods: Lunch purchases for 146 days of a school year were collected from 17 elementary schools (1^{st}-5^{th} grades) during August 2009-June 2010. Data were aggregated at the school level. The schools offered three entrées per day, and days were coded and categorized according to number of LF entrées offered (0, 1, 2) on a given day. Schools were also categorized by their average socioeconomic status (SES) through a frequency analysis of students on free/reduced lunch. Because no selection of LF entrées is possible when they are not offered, a 2(day) X 3(SES) ANOVA tested effects of day score (1,2) and school SES on LF entrée selection. A 3(day) X 3(SES) ANOVA was used to test school lunch participation.

Results: Significant differences in selection were found between days ($p<0.001$). LF entrée selections increased from 15.3% to 60.2% when the number of LF entrées offered increased from one to two. Differences in participation were found between SES groups ($p<0.001$) but not between days ($p=0.86$). Average participation rates in low SES schools (50.0%) and medium SES schools (50.0%) were significantly higher relative to high SES schools (44.4%);

$p<0.001$, while participation remained constant across all days (48.0%, 48.2%, and 48.3%). Conclusions: Increasing the number of LF entrées offered at school lunch results in a substantial increase in the selection of these foods, while maintaining participation rates in the school lunch program. This pattern is consistent across all SES groups.

Methods

Participants

De-identified data on lunch selection purchases were collected by food service staff for 17 schools (1st-5th grades) in Central Texas during the 2009-2010 school year (N=146 days). Demographic data (sex, ethnicity, and eligibility for free/reduced lunch) were obtained from official school records and linked to individual purchase data. For the purposes of this paper data were aggregated at the school level. Descriptive data are reported in the results section. Any child that ever purchased school lunch from August 2009 to June 2010 was eligible for this study.

Design

Schools

The participating Independent School District (ISD) was a large, suburban district of 17 elementary schools, with an average of 596.1 (±117.2) children enrolled per school and a range of 439-849. The sample was ethnically diverse (40.9% Hispanic, 30.0% White, 19.6% Non-Hispanic Black, 9.1% Asian/Pacific Islander, and 0.4% American Indian/Native Alaskan), with approximately half of the students (48.9%) reporting free/reduced lunch status. The Texas Education Agency (TEA) reported similar values for both ethnicity and free/reduced lunch status (49.1%), indicating that this sample was representative of the student population in this district. Schools were categorized for the analysis by their average SES through a frequency analysis of students on free/reduced lunch. Schools (N=5) with 17.4%-40.9% of total enrolled students on free/reduced lunch fell into the bottom third of the distribution and were classified as high SES; schools (N=6) with 43.9%-53.6% of total enrolled students on free/reduced lunch were classified as medium SES; and schools (N=6) with 55.1%-76.8% of total enrolled students on free/reduced lunch fell into the upper third of the distribution and were classified as low SES.

Menu

All schools in the ISD offer three entrées for lunch and each day's offerings are identical across all schools in the district. The menu is set by the Food Service Director who manages all cafeteria offerings for the ISD. Parents receive hard copies of the menu each month and can also access the menu online at any time to see that week's/month's offerings. The menu was not altered as a part of this study; nor was there any change in the preparation of the entrées to fit within any of the categories utilized in this study. Instead, this study was based on the naturally occurring variation in menu options as determined by the Food Service Director. This strategy was employed to increase generalizability of the data and to prevent criticism from food service employees that any positive impact on student entrée selections would be associated with increased costs or preparation times. The ISD participates in the CATCH program[75] and the menu items are designated as "go" (e.g. turkey sandwich on wheat, chef salad), "slow" (e.g. spaghetti and meat sauce, toasted cheese sandwich), and "whoa" (e.g. pepperoni pizza, cheese nachos) foods, indicated by green, yellow, and red dots, respectively, on the monthly calendar menu. While the ISD might have modified foods to fit within the go, slow and whoa categories, this occurred independently from this secondary data analysis.

Project staff worked with the foodservice director for the district and an independent registered dietitian to determine the fat content for each of the entrées. Entrées were coded as low-fat (LF) ($\leq$ 30% of calories from fat), moderate-fat (MF) (30 – 34.9% calories from fat), and high-fat (HF) ($\geq$ 35% calories from fat). It should be noted that not all LF entrées necessarily corresponded to "go" foods on the ISD menu; rather, the LF, MF, and HF designations were designed to align with USDA nutritional recommendations[76]. The ISD utilizes a central kitchen for all elementary schools and the food service staff at each school is responsible for heating and serving, with no support for additional ingredients. This largely eliminates differences amongst schools in preparation, taste, and fat content of the offered entrées. A sample of specific menu items and the corresponding fat content can be found in Table 1.

Table 1: Sample menu items and nutrition content of entrées offered at school lunch

Entrée	Total Calories	Fat Grams	Percent Fat	Fat Designation[a]	School Designation[b]
Yogurt & Fresh Fruit Plate	134	0.8	5%	LF	Go
Chicken Rice Soup	101	1.5	13%	LF	Go
Chili & Cheese Baked Potato	220	5.9	24.5%	LF	Whoa
Hamburger	259	7.5	26%	LF	Slow
Turkey Sandwich	224	7.5	30%	MF	Go
Ham Deli on Wheat	230	7.8	31%	MF	Go
Spaghetti & Meat Sauce	334	12	32%	MF	Go
Tony's Cheese Pizza	310	11	32%	MF	Slow
Hot Dog	220	11.5	47%	HF	Slow
Baked Steak Fingers	305	18	53%	HF	Slow
Crispy Taco	230	14	55%	HF	Slow
Baked Chicken Nuggets	240	15	56%	HF	Slow

Lunch Selection and Participation

WebSMARTT Point of Sale Software[77] was used to track the individual lunch purchases of each child throughout the school year. Within this system, each entrée is issued a unique code. In addition, each student in the ISD is issued a unique identification card. These cards are stored in the child's classroom and brought to lunch each day. The card is swiped every time the child selects an entrée and the food service staff enters the associated code for that days entrées. This system results in a data set that tracks the individual entrée purchases of each child throughout the year. The ISD provided these data, de-identified, including the school code for race/ethnicity, sex, grade, and free and reduced lunch status. To minimize the likelihood of data loss, purchases were downloaded from the ISD on a weekly basis, which were then merged with the full file.

Analysis

With three possible entrées available for purchase each day, there existed 10 possible combinations of LF-HF mixes: 1) LF, LF, LF, 2) MF, LF, LF, 3) HF, LF, LF, 4) MF, MF, LF, 5) HF, MF, LF, 6) MF, MF, MF, 7) MF, MF, HF, 8) LF, HF, HF, 9) MF, HF, HF, and 10) HF, HF, HF. Using these groupings, days were coded and categorized according to the number of LF entrées offered (0, 1, 2) on a given day. For example, a day offering the baked steak fingers (HF), the chili cheese baked potato (LF), and the bean soft taco (LF) would be categorized as a two. This "day score" was used as the independent variable in all analyses. Because only one day during the school year offered three LF entrées, this day was excluded from the analyses. All statistical analyses were performed using the Statistical Package for the Social Sciences (Version 21, 2013, IBM inc.). The primary dependent variables of interest in this study were 1) LF entrée selection and 2) participation in the school lunch program. Because no selection of LF entrées is possible when they are not offered, the day score simplified to a 2-level factor of either one LF offering or two LF offerings. This allowed for a 2 (day) X 3 (school SES) analysis of variance (ANOVA) to test the effects of day score (1,2) and school SES (low, medium, high) on LF entrée selection. Because we wanted to compare participation rates when a LF entrée was present to days when none were present, a 3 (day) X 3 (SES) ANOVA was used to test school lunch participation.

Results

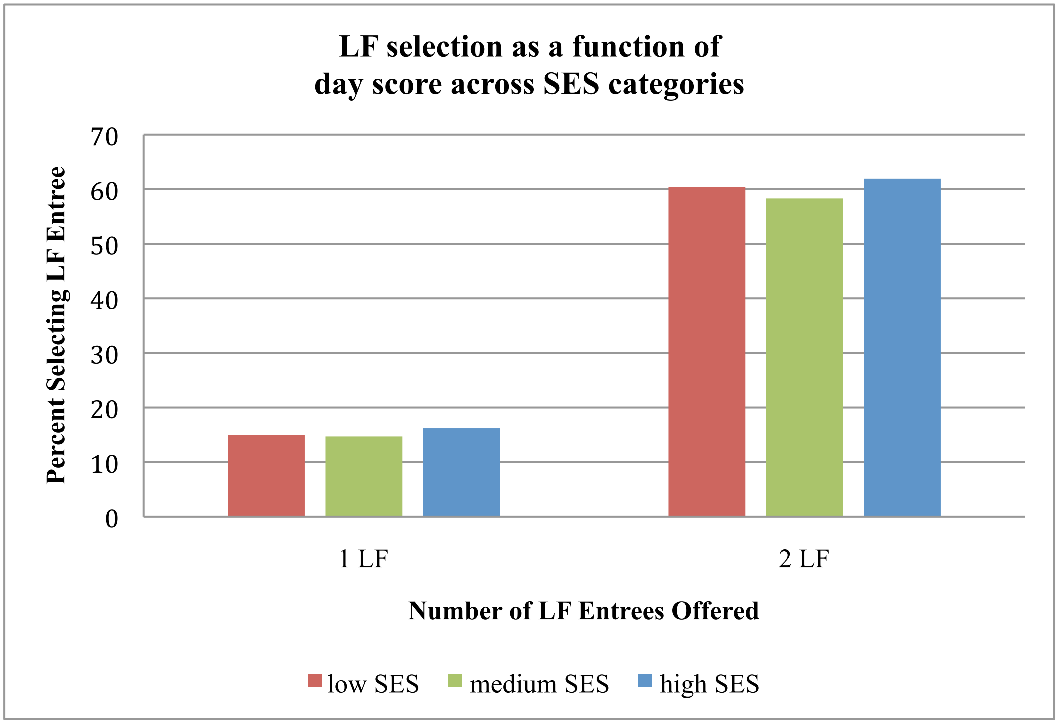
Participants

Participants were 10,134 students (47.8% female) enrolled in grades one (20.9%), two (19.6%), three (21.1%), four (19.4%), and five (18.9%) across all 17 elementary schools in the ISD. This represents the full, elementary population for the ISD during that academic year.

Low-fat Entrée Selection

Lunch selection and participation data were collected for a total of 146 days. Of these 146 days, 58 days (39.7%) did not offer a LF entrée, 55 days (37.7%) offered one LF entrée, 32 days (21.9%) offered two LF entrées, and one day (0.7%) offered three LF entrées. In order to address the first aim of this study, a 2 (day) X 3 (SES) ANOVA was conducted to test for significant differences in LF entrée selection between days offering one LF entrée and days offering two LF entrées. The day score and SES interaction term was non-significant ($p=0.84$), so it was deleted from the model, and a model with only the main effects was run. A significant main effect of day score was found for LF entrée selection ($F=759.07$, $p<0.001$). The number of LF entrée selections increased from 15.3% (±0.99) to 60.2% (±1.30) when the number of LF entrées offered increased from one to two. LF entrée selection did not differ as a function of SES group ($F=0.68$, $p=0.51$); with mean LF entrée selection rates similar across low, medium, and high SES categories for days offering one (14.9, 14.7, and 16.2%) and two (60.4, 58.3, 61.9%) LF entrées respectively (Figure 1).

Figure 1: LF selection at school lunch across days offering one and two LF options by SES category

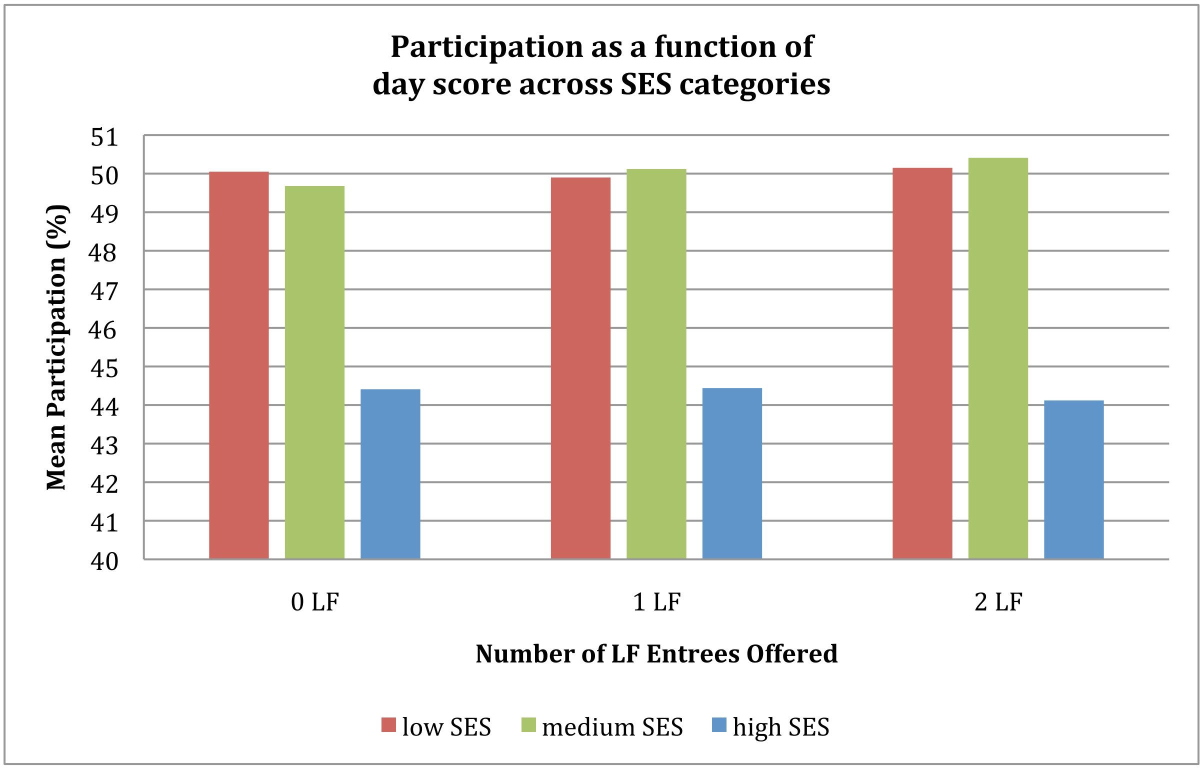


Participation

In order to address the second aim of this study, a 3 (day) X 3 (SES) ANOVA was conducted to test for significant differences in participation in the school lunch program across days offering zero, one, and two LF entrées. The day score and SES interaction term was non-significant ($p=0.84$), so it was deleted from the model, and a model with only the main effects was run. Participation rates did not significantly differ between days offering zero (48.0% ± 0.23), one (48.2% ± 0.24), and two (48.3% ± 0.31) LF entrées ($F=0.153$, $p=0.86$). There was a main effect of SES category on participation rates ($F=153.52$, $p<0.001$); therefore, Tukey's HSD tests for post-hoc comparisons were used to test for differences between groups. Results indicated that average daily participation rates in low SES schools

(50.0%) and medium SES schools (50.0%) were significantly higher relative to high SES schools (44.4%), (p<0.001) (Figure 2).

Figure 2: Average daily participation rates at school lunch across days offering zero, one, and two LF options by SES category



Validity Check

In this district, hamburgers were less than 30% calories from fat, and were therefore classified as a low-fat entrée. Because hamburgers are typically considered higher fat items, a separate analysis mimicking those above was done excluding all days that offered a hamburger as one of the three items for school lunch (N=21 days). The results mirrored those described above - a significant main effect of day score was found for LF entrée selection (F=97.371, p<0.001). The number of LF entrée selections increased from 9.26% (±0.582) to 29.25% (±1.03) when the number of LF entrées offered increased from one to two. LF entrée selection did not differ as a function of SES group (F=2.047, p=0.130); with mean LF entrée selection rates similar across low, medium, and high SES categories for days offering one (8.62, 8.62, and 10.52%) and two (29.75, 26.87, 31.23%) LF entrées respectively

We conducted a similar analysis with participation as the outcome variable on those days when hamburgers were not offered. In congruence with the previous analysis, participation rates did not significantly differ between days offering zero (48.04% ± 0.24), one (48.03% ± 0.26), and two (48.47% ± 0.45) LF entrées (F=0.412, p=0.66). There was a main effect of SES category on participation rates (F=126.42 p<0.001); therefore, Tukey's HSD tests for post-hoc comparisons were used to test for differences between groups. Results indicated that average daily participation rates in low SES schools (50.08%) and medium SES schools (50.06%) were significantly higher relative to high SES schools (44.4%), (p<0.001).

Discussion

This study was designed to assess the impact of menu construction on LF food selection and participation rates in the school lunch program in a large sample of elementary children. Results indicated a 45% increase in the selection of healthier foods when the offering of a LF entrée was increased from one to two options on a given day. In addition, participation rates in the school lunch program were maintained across all SES groups, despite changes in the availability of higher-fat (and traditionally more popular) options.

These results are consistent with previous literature, in that increasing the availability of LF entrées and concurrently reducing the number of higher-fat choices results in an increase in selection. Bartholomew and Jowers[71] implemented a two-phase environmental intervention that tested the effects of 1) increasing the frequency LF and MF entrées offered at school lunch and 2) reducing the number of competing HF entrées from two to one in a single elementary school. Their results found that simply increasing the number of days that a LF option was offered was not enough to significantly increase children's selection of these entrées. However, when the availability of HF entrées was reduced, so that only two entrées were offered per day, with one of these entrées low in fat, the selection rate of these foods was significantly higher compared to the control school (32.1% vs. 13.8%, respectively). Our results indicated a similar pattern, although the effects were more potent. Reasons for the larger increase in LF entrée selection rates (60% compared to 32%) could be due to the increased percentage of LF options available at a given time point. In the present study children selected from three possible entrées, and 66% of these were LF on days when a 60% selection rate was observed. Bartholomew and Jowers offered only two entrées, and thus only 50% of the available options were LF on any given day. In addition, the present findings represent the full district of 17 elementary schools and a far more diverse sample. As such, this study provides an important extension of the previous research.

The second major finding of this study was that participation in the school lunch program did not change as a function of the number of LF entrées offered on a given day. Average participation rates were nearly identical (48%) across days offering no LF options, one LF option, and two LF options. This finding is essential to changing food service directors and administrators beliefs about offering healthier menu items at school lunch. A qualitative study by Cho and Nadow[78] found that budgetary concerns are one of the top ranking barriers in the implementation of quality lunch programs. One superintendent stated that, "cost considerations necessitate selling unhealthy meals at the cafeteria because those, rather than healthy meals, are the foods that students like to buy (p. 426)." Our data do not support this belief, but rather provide evidence that participation rates, and thus revenue, can be maintained even when the availability of higher-fat options are reduced. There was only one day with three LF entrées offered. However, it is of interest that participation rates were reduced to 43.7% on this day. While we were unable to include such a small sample in the analysis, the reduction in participation rates suggests that there may be reaction to a menu that is limited to healthier items. This is an important topic for future research.

Participation did differ as a function of SES, with higher SES students showing an approximately 5.6% lower daily participation rate in the school lunch program than students with low or medium SES. This finding is expected, as previous research indicates that children who participate in the NSLP are more likely to have low income and to be certified for free or reduced-price meals[79]. What is notable, is that both lower and higher SES children maintained participation when two LF entrées were offered. Thus, despite the fact that higher SES children would be expected to have greater ability to bring their own lunch, they responded in much the same way as did lower SES children – with continued participation. This suggests that an intervention based on developing bound choices for children that reduce – without eliminating - the availability of less desirable foods can both increase selection rates of more desirable foods and maintain participation rates. This maintenance of participation rates should do much to reduce resistance from food service directors for this type of menu modification.

The healthfulness of school meals in this study was determined using dietary fat as the guideline, rather than, nutrient density, added sugars, total servings of fruits/vegetables in the entrées, etc. – all of which represent reasonable approaches. New USDA meal pattern regulations, released in 2012[80], do focus on overall nutritional quality (increased FV offerings, whole grains, low-fat milk, and limiting trans-fat), rather than total fat standards. The aim of this study was to demonstrate that changes in menu composition can drive student choice towards healthy foods. Thus the results are applicable to other changes, e.g. added sugars in school meals, including those outlined by the USDA guidelines. We elected to classify entrées as a function of their fat content based on the nutritional data provided to our staff by the Food Service Director. In addition, this pattern of effects did not differ on days in which hamburgers were not offered. The remaining LF entrées were more typical (e.g. cheese baked potato, vegetable soup, soft taco). This is notable, in the fact that a three-fold increase in the selection of LF entrées was observed on days that excluded the hamburger offering further strengthens the results of this study and demonstrates that simply increasing the availability of "typical" LF items can create positive changes in children's food choice.

Limitations

Results of this study should be interpreted with the awareness of several limitations. First, this study measured selection and not consumption of the LF, MF, and HF entrées. Thus, it is unclear if children were actually consuming the healthier foods purchased. Although it would have been ideal to support selection data with plate waste data, this method was beyond the scope of this study. However, the fact that daily participation rates were maintained over the course of two semesters suggests that children were consuming the LF foods purchased. Second, the LF categorization used for this study may potentially not apply to all "real-world" food outlets. For example, the hamburger served in this school district contained less than 30% of calories from fat, which is not consistent with hamburgers that can be purchased from typical fast food outlets. Despite this concern, as stated previously, the aim of this study was to demonstrate that by merely adjusting food choice, the odds of a child selecting a LF item are increased. Student choice was not manipulated through nutrition education efforts, and thus at no time were students told that "a hamburger was a healthy choice." It should be noted that schools did participate in the CATCH program at the time of data collection, and thus some knowledge related to healthy eating may have been communicated through this program. Third, it is possible that there may have been error associated with the foodservice staff keying the code for each entree purchased during the lunch period. Although our research staff requested to perform periodic validity checks, the foodservice director did not comply and requested to report their own accuracy percentages; mean cashier accuracy was reported to be 100% by the Aramark foodservice director during the time at which the data were collected. The error associated with this self-report is not expected to significantly influence the results of this study. Fourth, the National Center for Education Statistics defines a high poverty school as one in which more than 75% of the total enrolled students are eligible for free/reduced price lunch, and a low-poverty school as one in which 25% or less of total enrolled students are eligible. Therefore the low, medium, and high SES designations used for this study may not generalize to public schools nationwide. However, the categories defined for this study are inclusive of these cut-off points; it should be noted that a portion of the low SES schools in this study would not be classified as "low-poverty" across all states. Finally, for the purposes of this study, data were aggregated at the school level, and not analyzed individually. This limits the ability to test the potential moderation effects of individual level variables, such as sex, ethnicity, and age.

Conclusion

Offering more LF entrées will only be a useful intervention to the extent that it results in increased selections of these items without compromising participation rates. The present data support both outcomes. It is important to note that the LF offerings were not imposed on the ISD. Many interventions ask schools to modify their ingredients[81,82] or find other vendors[83] as a strategy to offering LF foods. In this case, we utilized the naturally occurring variation in the elementary menu for the analysis. This ensured that the LF entrées fit within the cost structure and the regularly selected vendors for the ISD. Taken together, the results of this study confirm behavioral economics theory[58], in that increasing the availability of LF items, while limiting those with a higher fat content, is a minimally invasive and cost-effective way to influence child behavior change. This offers a potential policy-based intervention that provides guidelines to districts as to the standards of the lunch menu, while allowing autonomy to the district in their choice of how to achieve this standard.

Chapter 4: Study Two: The effect of school lunch menu composition on low-fat food selection and participation rates in elementary children

Abstract

Background: One-third of school-aged children are overweight or obese, putting them at an increased risk for negative health consequences during childhood and as adults. Modification of the food decision environment in the school setting is one potential mechanism to impact healthy eating in youth.

Methods: Individual lunch purchases for one school year (N=147 days) were collected from 10,134 students (1^{st}-5^{th}) during August 2009-June 2010. The schools offered three entrées per day, and days were categorized according to the number of low-fat (LF) entrées offered (0, 1, 2) on a given day. Outcomes of interest included 1) student participation in the lunch program, and 2) selection of a LF entrée if he/she participated. Data were analyzed using separate two-level logistic hierarchical models.

Results: The model for participation demonstrated significant main effects for student SES ($p<0.001$) and ethnicity ($p<0.001$). The predicted probability of purchase was reduced by 0.17 when a student was classified as higher SES, and this effect was constant across days offering 0, 1, or 2 LF entrées. The predicted probability of purchase was 0.10 lower for white students compared to other, black, and Hispanic children and this was irrespective of day score. The predicted probability of LF entrée selection was 0.15 and 0.59 on days with one and two LF entrées, respectively, and these values were the same for all types of students.

Conclusions: Strong support exists for the modification of the lunch menu to "nudge" children towards healthy food choice. Implications are particularly potent for low-income and minority students.

Introduction

It is well known that US children consume excessive amounts of total fat, saturated fat, added sugars, and inadequate amounts of fruits and vegetables (FV) and whole grains. The most recent NHANES data indicates that 93% of all US children aged 1-18 years do not meet the MyPlate recommendations for daily vegetable consumption and 60% do not meet the recommendations for daily fruit intake[84]. In addition nearly all children (98%) consume less than the recommended intake of whole grains per day. Stratified data do show that some differences in subgroups exist. Lower income children are more likely to consume diets lower in FV and higher in fat content than higher income children[16], and both black and Hispanic children consume diets with a higher percentage of total energy from fat than white children[22,23]. These trends have persisted over the last three decades, suggesting that more potent interventions to change child-eating behavior are needed.

Because children can consume up to 50% of their total daily caloric intake at school[85], it is an ideal setting to target food behavior in this population. Past nutrition interventions, such as CATCH[75], tended to focus on individual change in order to impact behavior (e.g. changes in self-efficacy or knowledge for healthy eating). However, more recently, attention has shifted to broader, environmental and policy change strategies, aimed at improving food choices for the whole student population[47,48]. For example, Michelle Obama's "Let's Move" Campaign resulted in Congress' Healthy Hunger Free Kids Act of 2010, ultimately changing the National school lunch meal standards and increasing the availability of fruits and vegetables and whole grains for all students who participate in the school lunch program[86]. Similar changes in access to healthy foods, promotion of these foods, and price reductions have been implemented nationwide in an effort to influence food choice among youth[47,48]. Although some of these programs have been successful in changing behavior in the short-term, they are costly and maintenance of these changes following program cessation is difficult.

New cafeteria-based research has focused on engineering the environment in a way that will bias individuals towards healthy food decisions and minimize the resources needed to implement and maintain these changes. Pioneers in this area, such as Brian Wansink of Cornell University, use behavioral economic principles to design food environments in a way that makes healthy foods convenient, attractive, and normative for young children, rather than relying on knowledge or cognition to change behavior[74]. For example, Wansink and Colleagues[7] found that offering pre-sliced apples to middle school students, rather than whole pieces of fruit, increased average daily apple sales by 71% and decreased the number of students who wasted fruit by 48%. Similarly, giving vegetables attractive names, such as "X-Ray Vision Carrots," or "Power Punch Broccoli" significantly increased the selection of these vegetables in elementary school children during the intervention period. Even placement of white vs. chocolate milk in a cooler was effective in changing children's selection of these products[74].

These studies demonstrate that making healthy foods in the school cafeteria more convenient for children is effective, repeatable, and cost-efficient. The current study expands on this body of literature by examining how menu composition (e.g. the number of low-fat entrées offered at school lunch on a specific day) impacts participation in the school lunch program and the selection of healthier entrées in a large sample elementary students, using a mixed multi-level model and a natural manipulation of the food environment.

Methods

Participants

De-identified data on lunch selection purchases were collected by food service staff for 10,134 elementary students (1^{st}-5^{th} grades) in 17 schools in Central Texas during the 2009-2010 school year (N=147 days). Demographic data (sex, age, ethnicity, and eligibility for free/reduced lunch) were obtained from official school records and linked to individual purchase data. Outcomes of interest included

a) if the child purchased school lunch on that day (yes/no)

b) if he/she purchased school lunch, did he/she choose a low-fat (LF) entrée (yes/no)?

Any child that ever purchased school lunch from August 2009 to June 2010 was eligible for this study and their selections were included in the data set.

Design

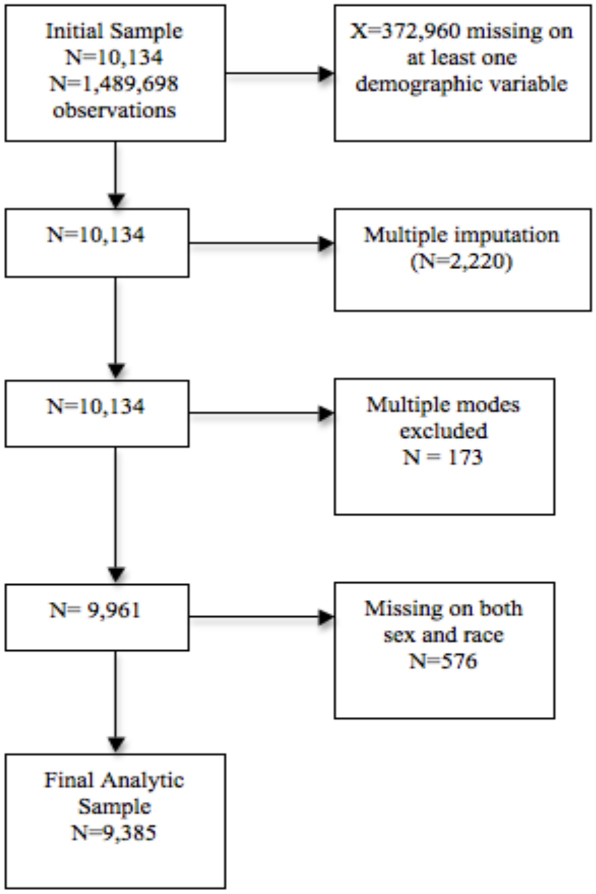
A detailed description of the menu design and the methods for the collection of the outcome variables (participation and LF selection) are described in a previous study[87]. All schools in the ISD offered three entrées for lunch and each day's offerings were identical across all schools in the district. Each menu entrée offered during the 2009-2010 school year was coded as low-fat (LF) ($\leq$ 30% of calories from fat), moderate-fat (MF) (30 – 34.9% calories from fat), or high-fat (HF) ($\geq$ 35% calories from fat) by an independent registered dietician. This study was based on the naturally occurring variation in menu options as determined by the Food Service Director, and the menu was not altered at any time point. The results of Korinek et al.[87] demonstrated a four-fold increase in LF entrée selection for all school SES groups when the number of LF entrées offered on a given day during the school year increased from one to two. Participation rates were constant across days offering zero, one, and two LF entrées. The primary limitation to this study was that the data were aggregated at the school level. The current study is designed to overcome this limitation.

The purpose of this study is to examine how the variation in the outcomes of interest (participation in school lunch and LF entrée selection) is explained by one day-level predictor (number of LF entrées offered) and four child-level predictors (gender, age, ethnicity, and SES) over time. A logistic two-level hierarchical linear model that partitions the variance in child participation and child LF entrée selection into two levels: day (i) (level one) and child (j) (level two) will be used. Two levels are appropriate because an examination of the intraclass correlation coefficient (ICC) when a third, school-level was included indicated that less than one percent of the variance in the outcome was between schools (ICC = 0.009, SE = 0.0035, 95% CI (0.004, 0.019). The primary outcomes of interest are interpreted as the predicted probability of a child: 1) participating in school lunch on a given day and 2) selecting a LF entrée for lunch if he/she participated that day. Separate models will be produced for each outcome.

Analysis

The initial dataset was comprised of 10,134 students and 168 days. Of these 168 days, 21 did not have information on the type of entrées offered for those days and were excluded from the analyses. Of the remaining 147 days of the 2009-2010 school year, students had outcomes on each day, yielding a total of 1,489,698 observations. Of these 1,489,698 observations, 372,960 (25.0%) were missing on at least one of the four demographic variables of interest (SES, gender, grade, or ethnicity). Because HLM cannot be performed when any of the level-two units contain missing data, multiple imputation was executed using STATA (version 11). This allowed us to address the missing data in a way that minimizes bias and the loss of precision and power that can occur when these individuals are excluded. For this data set, multiple imputation was used to estimate the missing level-two variable for individual *i* using data from complete cases and the other three values recorded for this individual (N=2,220). Due to the repeated measures structure of the data set, it was possible for multiple imputed values to occur within a given variable for a single individual. Therefore, for these individuals, the mode of the imputed values was computed and recorded for that variable. Any individual with multiple modes (n=173) was excluded from further analyses. Of these 9,961 students, 576 had received an imputed value for both sex and race/ethnicity and were excluded from the analyses. Thus, the final analytic sample was 9,385 (Figure 3).

Figure 3: Sample Determination



Separate level-one and level-two data sets were generated in SPSS (Version 21, 2013, IBM inc.). All two-level hierarchical logistic regression models were estimated using HLM (Hierarchical Linear and Nonlinear Modeling version 7.0) software. For each primary outcome, the following procedure was followed:

1) Estimation of the unconditional model (absent of predictors at any level). This partitions the variance in the outcome between students to provide a baseline for "improvement of fit" estimates.

2) Estimation of the random coefficients regression model (conditional at level-one only). This specifies the basic level-one model and describes how "day" characteristics relate to either student participation or LF entrée selection.
3) Estimation of the intercepts and slopes as outcomes model (conditional at level-one and level-two). This models differences in level-one coefficients with level-two variables and describes how the effects of these variables vary across students.
4) Exploratory analysis of cross-level interactions (examines how the relationship between the level-one predictor (day score) and the outcome (participation or LF entrée selection) differs across level-two variables of interest (e.g. student SES, ethnicity, etc.). This estimates a unique slope for any level-two predictor of interest.

Results

Participants

Participants were 9,385 students enrolled in grades one (21.9%), two (18.9%), three (22.2%), four (18.7%) and five (18.1%), with 47.84% female and 48.1% on free/reduced lunch status. The sample was 30.1% white, 40.8% Hispanic, 19.55% Black, and 9.55% other. Data on the primary outcomes of interest were collected for 147 days of the 2009-2010 school year, yielding a total of 1,379,595 observations. The mean participation rate across all students and all days was 50.01%, with 40.1% of these days offering zero LF entrées for school lunch, 38.1% offered one LF entrée, and 21.8% offered two LF entrées for lunch.

Participation Model

The unconditional model for student participation in school lunch yielded a level-two variance of 5.42 ($X^2 = 462{,}123.84$, $p<0.001$) and an intraclass correlation coefficient of 0.622, suggesting that 62.2% of the variance in school lunch participation is between students. In all additional models, the level-two explanatory variables were grand-mean centered to allow for meaningful interpretations of the outcome (e.g. the effect of student SES, while holding gender, ethnicity, and grade-level constant). The results of the random-intercepts (fixed slope) model yielded a level-two variance of 5.01 ($X2 = 475{,}924.09$, $p<0.001$). The random-intercepts-and-slopes model yielded a reliability of 0.952 for the intercept and 0.362 for the slope, and a level-two variance of 4.37, corresponding to a proportion of variance explained (PVE) of 19.37%. Therefore, based on the model fit criteria specified and a prior hypothesis that participation rates will vary across each type of day (0, 1, and 2) as a function of student characteristics, the random-intercepts-and-slopes model was chosen as the best model for this outcome.

The results and equations for this model are presented in Table 2. Significant main effects were found for the intercept ($B0 = -0.27$, $t = -12.25$, $p<0.001$), student SES ($B03 = -0.70$, $t = -15.88$, $p<0.001$), other ethnicity ($B04 = 0.36$, $t = 4.72$, $p<0.001$), black ethnicity ($B05 = 0.44$, $t = 7.203$, $p<0.001$), Hispanic ethnicity ($B06 = 0.41$, $t = 7.77$, $p<0.001$), and the day score slope ($B10 = -0.01$, $t = -3.317$, $p = 0.001$).

Figure 4 details the significant main effect of student SES. Holding all other level-two explanatory variables constant, lower SES students are two times more likely to purchase school lunch across all types of days than high SES students. Specifically, the predicted probability of purchase is reduced by 0.17 when a student is classified as higher SES, and this effect is constant across days offering zero, one, or two LF entrées for lunch. Figure 5 details the significant main effect of student ethnicity. Holding all other level-two explanatory variables constant, white students are 1.5 times less likely to purchase school lunch compared to other, black, and Hispanic children across all types of days. The predicted probability of purchase is 0.10 lower for white students and this effect is irrespective of day score.

Table 2: The-Random-Intercepts-and-Slopes Model for Participation

Level 1 Model
Prob(Y=1|B) = P log[P/(1-P)] = P0 + P1*(DayScore)
Level 2 Model
P0 = B00 + B01*(SEX) + B02*(GRADE) + B03*(SES) + B04*(OTHER) + B05*(BLACK) + B06*(HISPANIC) + r0 P1 = B10 + r1
Mixed Model
eta = B00 + B01*SEX + B02*GRADE + B03*SES + B04*OTHER + B05*BLACK + B06*HISPANIC + B10*DayScore + r0 + r1*DayScore

Fixed Effect	**Coefficient**	**SE**	**T-ratio**	**df**	**P-value**
For Intercept, P0					
Intercept, B0*	-0.269622	0.022015	-12.247	9378	0.000
Sex, B01	-0.048692	0.040235	-1.21	9378	0.226
Grade, B02	0.026289	0.014333	1.834	9378	0.067
SES, B03*	-0.703327	0.044286	-15.881	9378	0.000
Other, B04*	0.360934	0.076506	4.718	9378	0.000
Black, B05*	0.445121	0.0618	7.203	9378	0.000
Hispanic, B06*	0.409635	0.052692	7.774	9378	0.000
For Slope, P1					
Intercept, B10*	-0.01399	0.004217	-3.317	9384	0.001
Random Effect	**SD**	**Variance**	**df**	**Chi-Square**	**P-value**
Intercept, ro*	2.09146	4.37419	9378	207264.6393	0.000
Day Score Slope, r1*	0.25281	0.06391	9384	12501.31217	0.000

Figure 4: The Effect of Student SES on the Predicted Probability of Participation

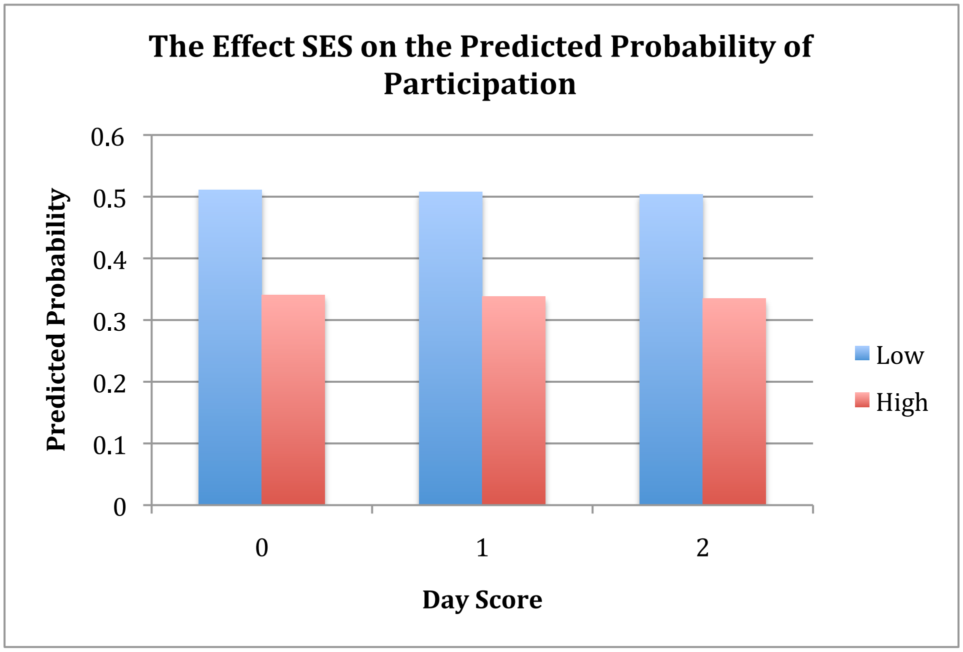
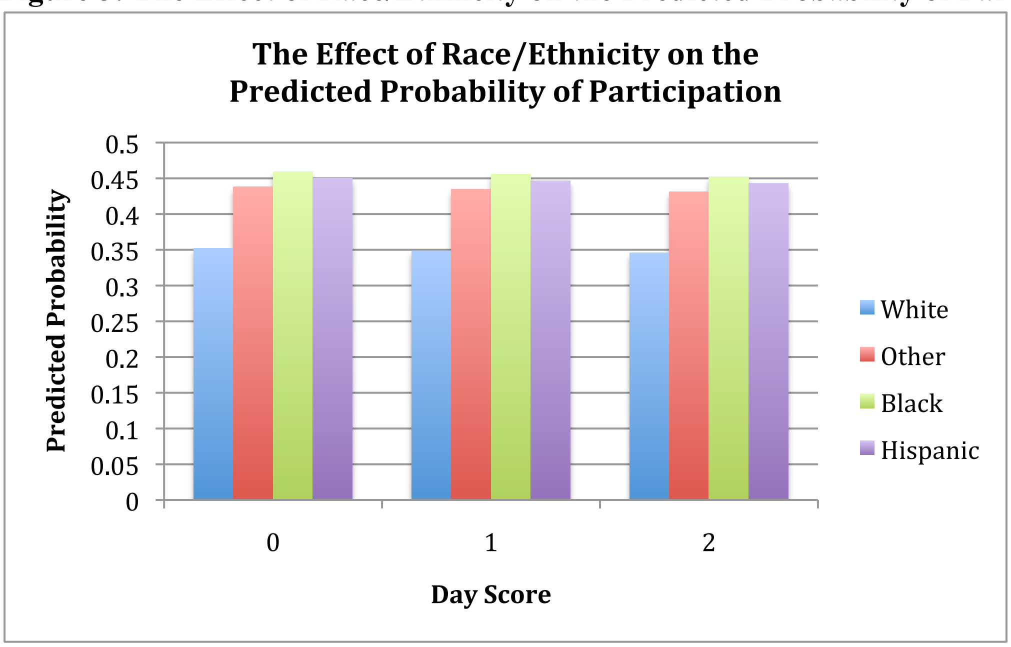


Figure 5: The Effect of Race/Ethnicity on the Predicted Probability of Participation



Cross-level Interactions

Because significant main effects were observed for both student SES and ethnicity, and the level-one slope was found to significantly vary across level-two units, separate models examining the interaction effect of each of these variables and day score on the predicted probability of participation were conducted as an exploratory analysis. In each of these models, an interaction term is added at level-two to account for the effect of either student SES or ethnicity on the day-score slope.

The results and equations for the SES cross-level interaction are presented in Table 2. The SES slope, B11, is significant (B11 = -0.12, t = -14.35, $p<0.001$) indicating that participation on days offering zero, one, and two LF entrées is dependent on SES status. Specifically, SES has a large, negative effect on participation, in that high SES children have a reduced predicted probability of participation across all types of days (0.28, 0.26, and 0.23) compared to low SES children (0.51, 0.50, and 0.50) on days 0, 1, and 2 respectively (Figure 6). The estimation of a unique SES slope had little to no effect on participation rates for low SES students (Figure 7). In addition, all ethnicities had a reduced predicted probability of participation across all days when the unique SES slope is included in the model (Figure 8).

The results and equations for the ethnicity cross-level model are presented in Table 4. The ethnicity slopes, B11, B12, and B13 are all significant (B11 = 0.07, t = 4.60, $p<0.001$, B12 = 0.15, t = 12.11, $p<0.001$, B13 = 0.09, t = 9.12, $p<0.001$), indicating that participation on days offering zero, one, and two LF entrées depends on student ethnicity. Specifically, the addition of a unique race/ethnicity slope had a positive effect on the predicted probability of participation across all days for other, black, and Hispanic children, while the probability of participation across each type of day remained unchanged for white children (Figure 9). The greatest effect is seen for black children, whose predicted probabilities of participation increased to 0.54, 0.57, and 0.61 on days of 0, 1, and 2, respectively.

Table 3: Cross-level Interaction Model for Student SES

Level 1 Model
Prob(Y=1|B) = P log[P/(1-P)] = P0 + P1*(DayScore)
Level 2 Model
P0 = B00 + B01*(SEX) + B02*(GRADE) + B03*(SES)+ B04*(OTHER) + B05*(BLACK) + B06*(HISPANIC) + r0 P1 = B10 + B11*(SES) + r1
Mixed Model
eta = B00 + B01*SEX + B02*GRADE + B03*SES + B04*OTHER + B05*BLACK + B06*HISPANIC + B10*DayScore + B11*(SES)*DayScore + r0 + r1*DayScore

Fixed Effect	**Coefficient**	**SE**	**T-ratio**	**df**	**P-value**
For Intercept, P0					
Intercept, B0*	-0.270015	0.021931	-12.312	9378	0.000
Sex, B01	-0.049258	0.039723	-1.24	9378	0.215
Grade, B02	0.025427	0.014151	1.797	9378	0.072
SES, B03*	-0.961763	0.047628	-20.193	9378	0.000
Other, B04*	0.34815	0.075565	4.607	9378	0.000
Black, B05*	0.426455	0.061002	6.991	9378	0.000
Hispanic, B06*	0.392969	0.052007	7.556	9378	0.000
For Slope, P1					
Intercept, B10*	-0.015308	0.004227	-3.621	9383	0.000
SES, B11*	-0.121446	0.008463	-14.35	9383	0.000
Random Effect	**SD**	**Variance**	**df**	**Chi-Square**	**P-value**
Intercept, ro*	2.08316	4.33957	9378	212726.5716	0.000
Slope, r1*	0.25474	0.06489	9383	12575.1197	0.000

Figure 6: Predicted Probability of Participation with SES Slope

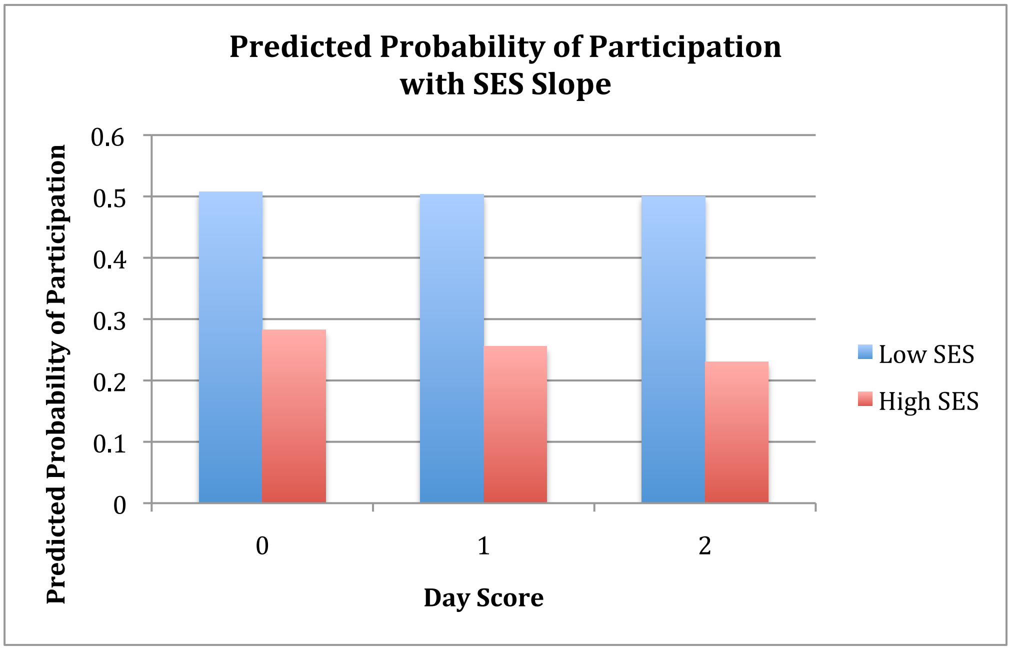


Figure 7: Comparison of Final Model to SES Cross-level Model

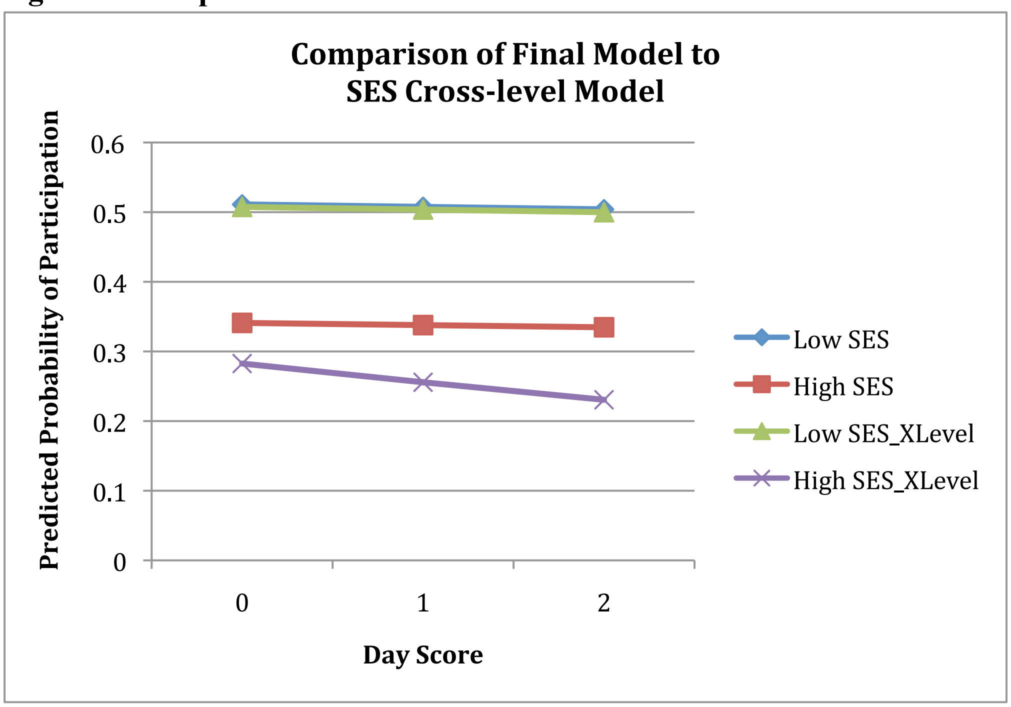


Figure 8: Effect of SES slope on Predicted Probability by Race/Ethnicity

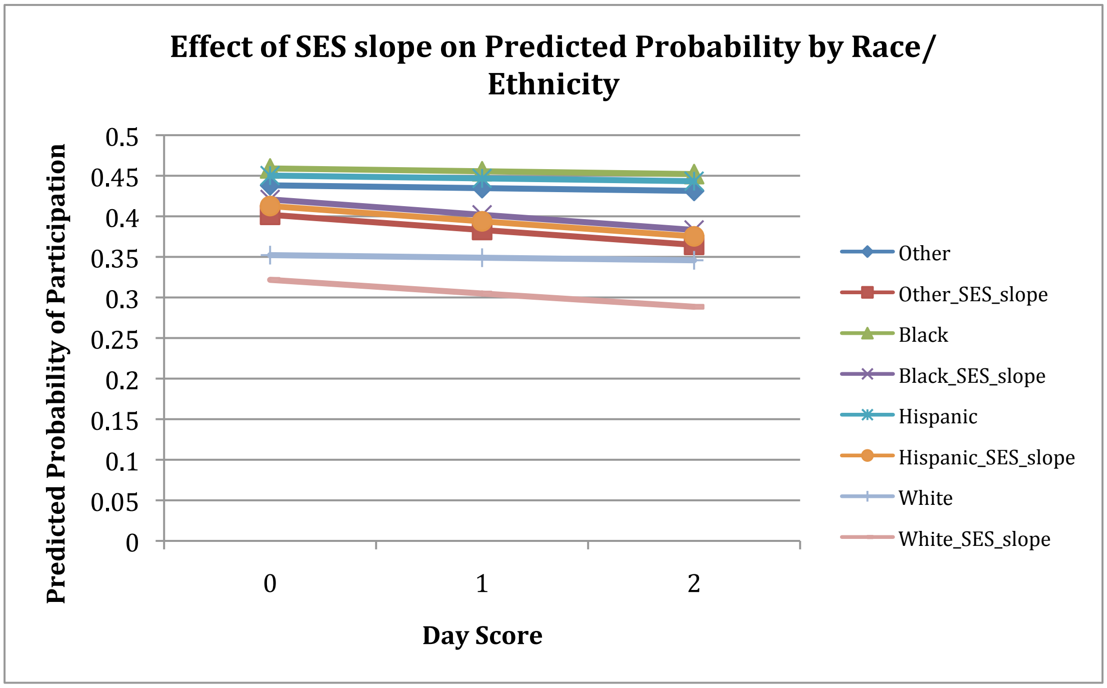


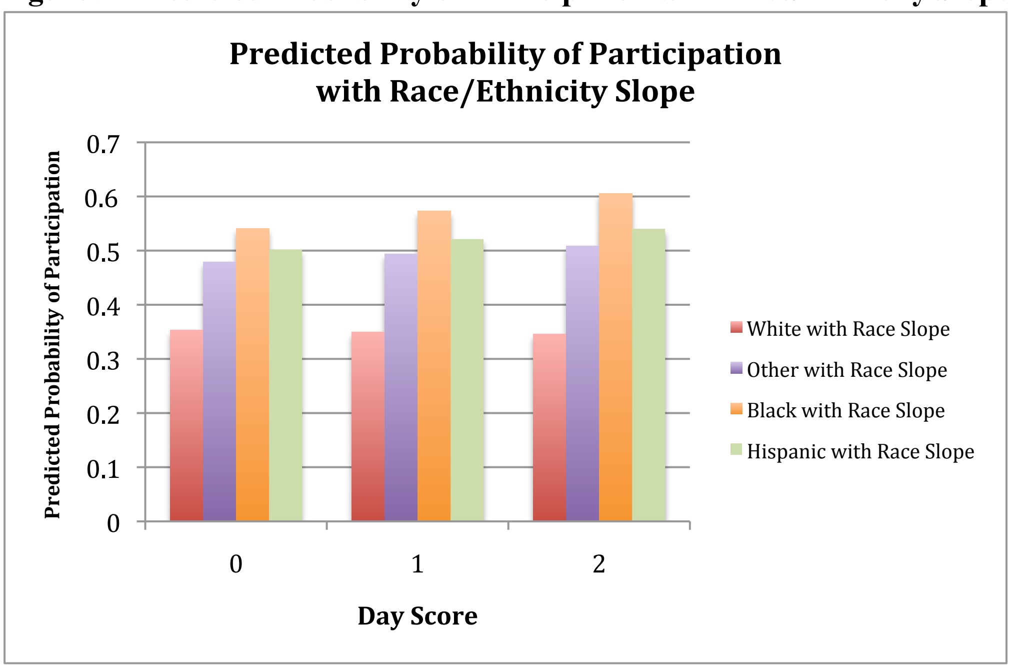
Table 4: Cross-level Interaction Model for Student Race/Ethnicity

Level 1 Model
Prob(Y=1|B) = P log[P/(1-P)] = P0 + P1*(DayScore)
Level 2 Model
P0 = B00 + B01*(SEX) + B02*(GRADE) + B03*(SES) + B04*(OTHER)+ B05*(BLACK) + B06*(HISPANIC) + r0 P1 = B10 + B11*(OTHER) + B12*(BLACK) + B13*(HISPANIC) + r1
Mixed Model
eta = B00 + B01*SEX + B02*GRADE + B03*SES + B04*OTHER + B05*BLACK + B06*HISPANIC + B10*DayScore + B11*(Other)*DayScore + B12*(Black)*DayScore + B13*(Hispanic)*DayScore + r0 + r1*DayScore

Table 4, Cont.

Fixed Effect	Coefficient	SE	T-ratio	df	P-value
For Intercept, P0					
Intercept, B0*	-0.269406	0.021957	-12.270	9378	0.000
Sex, B01	-0.049637	0.039895	-1.244	9378	0.213
Grade, B02	0.025739	0.014213	1.811	9378	0.070
SES, B03*	-0.688472	0.043912	-15.678	9378	0.000
Other, B04*	0.520900	0.082887	6.284	9378	0.000
Black, B05*	0.766440	0.067009	11.438	9378	0.000
Hispanic, B06*	0.611326	0.056907	10.742	9378	0.000
For Slope, P1					
Intercept, B10*	-0.015764	0.004223	-3.733	9381	0.000
Other, B11*	0.073785	0.016027	4.604	9381	0.000
Black, B12*	0.148009	0.012223	12.109	9381	0.000
Hispanic, B13*	0.092570	0.010150	9.120	9381	0.000
Random Effect	**SD**	**Variance**	**df**	**Chi-Square**	**P-value**
Intercept, ro*	2.08569	4.35011	9378	210590.75608	0.000
Slope, r1*	0.25387	0.06445	9381	12523.11996	0.000

Figure 9: Predicted Probability of Participation with Race/Ethnicity Slope



LF Entrée Selection Model

The unconditional model for LF entrée selection yielded a level-two variance of 0.065 (X^2 = 14,558.73, p<0.001) and an intraclass correlation coefficient of 0.0195, suggesting that only 1.95% of the variance in LF entrée selection is between students. Therefore, based on these results, the random coefficients model was estimated by adding the explanatory variable of interest (day score) to this model to assess the relationship between this variable and the outcome. The results and equations for this model are presented in Table 5. The value of the B00 coefficient was –3.86 (t=-301.40, p<0.001) and the value of the day score slope, B10 was 2.12 (t=278.21, p<0.001), corresponding to predicted probabilities of 0.15 and 0.59 on days with one and two LF entrées, respectively. The level-two variance associated with this model was 0.11 (X^2=16,477.62, p<0.001). Because less than 2% of the variance in this outcome is between level-two units, this is the best model to fit this data. This was expected given the results of the aggregated data from Korinek et al.[87], which demonstrated a 45% increase in the selection of healthier foods when the offering of a LF entrée was increased from one to two options on a given day. A random intercepts model was examined as a means to demonstrate the similarities in selection behavior between all students, regardless of gender, SES, race/ethnicity, and/or grade on each type of day. The predicted probability of LF entrée selection ranged from 0.138-0.148 on days offering one LF entrée and 0.570-0.591 on days offering two LF entrées for all groups. The tables for these results are included in Appendix C.

Table 5: The Random Coefficients Model for LF Entrée Selection

Level 1 Model
Prob(Y=1|B) = P log[P/(1-P)] = P0 + P1*(DayScore)
Level 2 Model
P0 = B00 + r0 P1 = B10
Mixed Model
eta = B00 + r0 + B10*DayScore + r0

Fixed Effect	Coefficient	SE	T-ratio	df	P-value
Intercept, B0*	-3.862369	0.012815	-301.398	8688	0.000
Slope, B10*	2.11666	0.007608	278.211	407719	0.000
Random Effect	**SD**	**Variance**	**df**	**Chi-Square**	**P-value**
Intercept, ro*	0.3353	0.11242	8688	16477.61888	0.000

Discussion

This study aimed to explain the variance associated with participation in the school lunch program and the selection of healthier menu items through the use of mixed multi-level modeling. This analysis allowed for the appropriate assessment of the nested structure of student outcomes within days. The results of this study indicated that the predicted probability of participation in school lunch significantly varied across type of day, as a function of both student SES and student ethnicity. In contrast, little to no variation existed in LF entrée selection between students; meaning that boys and girls, white, black, and Hispanic students, and both low and high SES children had similar odds of selecting a low-fat entrée on each type of day. The difference in the probability of selecting a LF entrée was entirely attributed to the number of LF options available to the student on that day.

Effect of Student SES on Participation

The final model for participation showed that student SES had a significant impact on whether or not the child purchased school lunch across days offering zero, one, or two LF entrées. Specifically lower SES students had a predicted probability of participation of 0.51 on days with zero and one LF offerings and 0.50 on days with two LF offerings. In contrast, higher SES students had a predicted probability of participation of 0.35, 0.34, and 0.33 on each of these days, respectively. A cross-level term was added to the model to further understand the moderation effect of SES on the relationship between the outcome (participation) and the number of LF entrées offered on a given day (day score). The results of the cross-level model showed that the addition of a unique SES slope had little to no effect on the predicted probability of participation for lower SES children (probabilities were 0.51, 0.50, and 0.50 on zero, one, and two days). However, it further reduced the predicted probability of purchase across each type of day for higher SES children (0.28, 0.26, and 0.23, respectively). In practical terms, this corresponds to an average of 2,250 lower SES children likely to participate on any type of day (zero, one, or two), while 1,360, 1,270, and 1,120 higher SES children are likely to participate on days offering zero, one, and two LF entrées, respectively. Although this represents some decrement in participation rates for these children, this is a very small number over the total sample (loss of 240 students over 10,000) (Figure 10).

Figure 10: Number of Children Likely to Participate Across Days

Day	0	1	2
Low SES	2250	2250	2250
High SES	1360	1270	1120

It is well known that NSLP participants are more likely to be of low-income and on free or reduced lunch status[79]. However, this study demonstrates a novel finding, in that these lower-income students participate at equal rates, regardless of the type of entrées offered. Gleason and colleagues[79] previously used a fixed effects model to demonstrate differences in dietary intake between NSLP participants and non-participants. Their results found that participants were more likely to consume milk and meat—foods provided by the NSLP—while nonparticipants were more likely to consume soft drinks and fruit drinks—foods not provided by the NSLP. The present study adds an important piece to this literature, in that the children who are most at risk for overweight and obesity[1] will purchase the foods provided to them by the school lunch program, even when these items are "healthier." In addition, food service staff can have confidence in the profitability of serving these items at school lunch, without a concomitant loss in profits.

Effect of Race/Ethnicity on Participation

The second major finding of the final model for participation was that student ethnicity had a significant impact on student purchasing behavior across days offering zero, one, or two LF entrées. Specifically, white children were less likely to purchase school lunch on any day (0.35, 0.35, and 0.34 on zero, one, and two days, respectively) compared to all other race/ethnicity categories (average = 0.45, 0.45, and 0.44, respectively). This interaction was further explored by adding a cross-level term to the model (Table 3). The results of the cross-level model showed that the addition of a unique ethnicity slope had no effect on the predicted probability of participation for white children (probabilities were nearly identical to those observed in the random intercepts and slopes model and equal to 0.35 on all types of days).

However, it increased the predicted probability of participation for all other race/ethnicity categories with the largest increase observed for Black students (Figure 13; 0.54, 0.57, and 0.61 on days with zero, one, and two LF entrées offered, respectively).

These findings were expected, given the results of the SES cross-level model. This model showed that low-income children are more likely to be non-white and more likely to participate than high-income children. In addition to being the most likely to purchase a school lunch, black children also have the steepest day score/participation slope compared to all other races/ethnicities. The reasons for the increased probability of participation on days when two LF entrées were offered compared to other non-white children is not clear. This could be due to differences in preference for the entrées offered on “2” days compared to other children in this sample. Previous researchers have demonstrated differences in food preference by ethnic status[88], as well as differences in child-parent feeding practices due to acculturation[89], which could influence meal choice at school. For example, in low-income Hispanic adults, acculturation is associated with dietary choices that increase the risk of obesity[89]. Children from these households may be more likely to choose foods that are not typically classified as “low-fat.” If these items were offered at a higher frequency on days classified as one or zero, this may have impacted participation of this sub-group on days when two LF entrées were offered. Likewise, children in the “other” race/ethnicity category had the lowest predicted probability of participation across all three types of days, which may be representative of the lack of menu items in this district that reflect the variation in culture within this sub-sample.

LF Entrée Selection

The final model for LF entrée selection showed that the number of menu offerings that were classified as "low-fat" accounted for all of the variance in this outcome for these data. In fact, less than two percent of the variance was between students, meaning that all types of students had greater odds of selecting a LF entrée when it was offered alongside only one other higher fat option. As was demonstrated Korinek et al.[87], the difference in the predicted probability of selection was 0.45 between days offering one versus two LF options.

These results provide strong support for the use of choice architecture in school lunch menu construction to impact low-income, minority students. The multi-level model for participation indicated that low SES, Black and Hispanic children have the greatest participation rates, independent of menu offering. Only children who participated in school lunch were included in the model for entrée selection, and therefore the effect of menu offering is most potent for these children. This is important because these children tend to have the highest prevalence of overweight and obesity when compared to white children[90], and tend to have less healthy options available in the home[91].

Limitations

Some limitations of this study should be noted. First, selection and not consumption was used as the primary outcome. It is possible that the students were not consuming the low-fat items purchased, resulting in the consumption of potentially less healthy and more calorically dense foods outside of the school setting. Ideally plate waste and/or sub-sample observations should be paired with selection data to verify that children were eating the foods purchased in the cafeteria. Second, the focus in this study was on "low-fat" as an indicator of the healthfulness of the meal and the selection of side items was not collected as part of these data. The new USDA guidelines for school meals focus on the servings of fruits and vegetables, whole grains, saturated fats, and low-fat milk, rather than total fat of the main entrée. However, the expectation is that these results would apply to changes in the availability of these items as well. Third, this analysis did not assess if there was an effect for the higher-fat item that was offered in conjunction with the lower-fat items. For example, if lasagna was always offered with two LF items and lasagna was not well-liked among children in this sample, selection of the lower-fat item could have been biased. However, the large sample size and mixed model analysis utilized in this study lessens the chance of potential bias from this effect. Fourth, this analysis was unable to distinguish between students who were merely absent from school and thus did not participate in school lunch, and those that were present and did not participate. However, this condition is expected to be randomly distributed across all types of days and thus would not bias the current results. Finally, schools in this district also offer breakfast each day. Data for breakfast purchasing was not made available for this analysis, and thus it is possible that students who purchased breakfast at school may have selected a different entrée at lunch than those who did not purchase breakfast. For example, if sausage was offered at breakfast, students may be less likely to purchase a similar lunch entrée. Future studies should consider breakfast options and the impact of these foods on child purchases at school lunch.

Conclusions

This study provides a robust analysis of the school lunch purchasing behavior of a large sample of elementary school students. Lower-income and minority students are more likely to participate in the school lunch program than wealthier and/or white students and the likelihood of participation in these students is similar - even when higher fat items are eliminated from the menu choices. Instead of "opting-out" of the school lunch program, these children, instead, continue to buy school lunch and are 8.3 times more likely to choose a LF option when the availability of these items is increased from one to two of three entrees offered on a given day. Future policy makers should consider these results in menu planning with the expectation that profitability of the school lunch program will not be compromised.

Chapter 5: Discussion and Implications

This two-study dissertation was designed to assess the impact of menu composition on the purchasing behavior of elementary children in schools. The first study of this dissertation demonstrated there was a four-fold increase in the selection of LF entrées when more than a single LF entrée was offered at school lunch on a given day. These results were consistent across school-level SES groups. However, this increase is of little use if children refrain from purchasing a lunch at school. As a result, this dissertation was also designed to assess participation rates. Results indicated that participation rates were consistent across schools, despite increases in the offering of lower fat entrées. The primary limitation to this study was that data were aggregated at the school-level. To address this limitation, the second study in this dissertation aimed to explain the variance associated with the individual selections of lower fat menu items as a function of menu construction. This multi-level analysis indicated that the difference in the probability of selecting a LF entrée was entirely attributed to the number of LF options available to the student on that day. The more LF entrées offered, the greater the selection of these entrées – regardless of student demographics. In fact, all types of students were over eight times more likely to select a LF entrée when it was offered alongside only one other higher fat option.

These results are consistent with findings from Bartholomew and Jowers[71], which demonstrated that children increased their selections of lower and moderate fat entrées, only when the availability of higher fat entrées was reduced. During the first phase of this earlier study, children in the intervention schools could select from among three entree offerings, one of which was lower in fat; while in phase two, those children could select between only two entree offerings, one of which was lower in fat. Results showed that lower-fat entrees were selected more than twice as often when they were paired with one rather than two alternative entrees. This suggests that increasing choice of LF entrées and decreasing the availability of HF entrées can drive child selection of healthier foods in the school setting.

The results of the current study offer a more robust test of these behavioral economic principles. Rather than a focus on a small number schools, the present dissertation examined data from all students in a large, diverse school district. This allowed for an assessment of student demographics that did not occur in the earlier work. Specifically, the multi-level model for participation indicated that lower SES, Black and Hispanic children have the greatest participation rates in the school lunch program. In addition, participation levels did not vary with menu offering. This is critical as only children who participated in school lunch can benefit from the change in menu offerings. In this case, only those who participated were included in the model for entrée selection. With lower SES students participating at just over 50% each day, the demonstrated eight-fold increase in the selection of LF entrées was most potent for these children. This is important because these children tend to have the highest prevalence of overweight and obesity when compared to higher income and white children[90], and tend to have less healthy options available in the home[91].

These results are also consistent with Dr. Brian Wansink's theory that making healthy foods convenient, attractive, and normative for children will drive their selection, and that this is more effective than providing education and knowledge to change eating behavior in this population[74]. Convenience can relate to how easy the food is to see, grab, and eat (e.g. pre-packaged salads and fruit cups), as well as how it is presented (e.g. cut apples and pears for young children)[74]. The current study changed the convenience of healthy food items by making them more available. Children saw one more healthy and one less unhealthy entrée on the menu. Thus, it was "easier" to choose something that was classified as LF. Because food decisions involve quick and instinctive actions, this simple modification is extremely effective, without completely removing autonomy. Secondly, by offering more LF entrées at lunch on a given day, the action of selecting one of these foods is likely to become more normative among this sub-group of elementary children. For example, Wansink demonstrated that when 50% of the milk in a cooler is white (versus chocolate), kids are nearly three times as likely to take a white milk than when only 10% is white[74]. When children see two out of three "green" or "healthy" menu items offered, it seems "normal" to select one of these foods for lunch. In addition, repeating this menu pattern throughout the school year has the potential to reinforce these behaviors.

The impact of these effects is inherently dependent upon children's continued participation in the school lunch program. Food service directors will not increase the number of LF entrées and side items offered if profitability decreases across the district and the benefit of increasing healthy items is lost if children opt out. Although participation varied as a function of student SES and student ethnicity, there was no impact of the number of LF entrées offered on participation rates. The predicted probability of purchase was consistent across all types of days for each of these subgroups. Therefore, both food service directors and public health researchers can be confident in making policy changes that modify the food decision environment and "nudge" children towards healthier lunch selections.

Limitations

As described in the previous chapters, the chief limitation of this dissertation was that selection and not consumption was used as the primary outcome. Future studies should include plate waste measurement and/or sub-sample observations to verify that children are consuming the foods selected during lunch. Secondly, fat content was used to gauge the healthfulness of the school meals, rather than servings of fruits and vegetables, whole grains, or the percent of saturated fat. However, it is expected that the results demonstrated in these two studies would be replicated using these alternative classification methods. Finally, these analyses were unable to distinguish between students who were absent from school and thus did not participate in school lunch, and those that were present and did not participate. However, this condition is expected to be randomly distributed across all types of days and is not likely to bias the current results.

Practical Recommendation / Best Practices

Constructing the school lunch menu in a way that offers a greater number of low-fat foods appears to be effective in changing child dietary behavior across all subgroups. Thus, it is recommended that food service and school district management pursue changes to the menu to increase the frequency of healthier options. Policy changes to the school lunch menu such as this do not require additional funds, resources, or changes in ingredients or food production.

That is, the present study simply examined the natural variation in entrées offered. Thus, all entrées fit within the existing policies of the food service management company. As this was a national-level school lunch provider, these policies likely reflect practices of other settings. The recommended policy change would simply focus on an increase in frequency of these existing entrées. The primary concern is that such change will undermine participation in the school lunch program. The present study contradicts that fear. There was not an appreciable change in participation when LF foods increased from 0% to 66% of offered entrées. Thus, there is little reason to resist the recommended policy change.

Conclusions

This dissertation provides a robust analysis of the school lunch purchasing behavior of a large sample of elementary school students. Constructing the school lunch menu in a way that offers a greater number of low-fat foods is effective in changing child dietary behavior across all subgroups. Policy changes to the school lunch menu such as this do not require additional resources, are easy to implement, and do not change participation rates. The current study provides a foundation for future research in this area and offers a strong application of the effectiveness of choice architecture in this population.

Appendices

Appendix A: Background on Hierarchical Linear Modeling

Hierarchical Data Structure

In behavioral and social science research, multi-level modeling is often necessary to address the nested structure of the data (e.g. students within classrooms within schools). Most traditional statistical analyses assume independence of observations; however, when people are clustered within naturally occurring units (such as schools or workplaces), observations can no longer be assumed to be independent and it is likely that individuals within the same unit will be more similar to one another than individuals across units[92]. With HLM each of the levels in this structure is represented by its own submodel, which specifies how variables at one level influence the outcome across multiple levels[93].

Advantages of HLM

First**,** multi-level modeling allows the researcher to explain both the within and the between cluster variability in the outcome of interest[92]. This is accomplished through the use of predictors at both the lowest level (level-one) and higher levels (two and three) of the full model. For example, student daily FV consumption can be entered as a level-one predictor of child weight status, while school availability of fresh fruits and vegetables can be entered as a level-two predictor of child weight status. In each additional model, the researcher explains greater variance in the outcome. Second, HLM allows the researcher to simultaneously model moderation effects through the use of cross-level interactions. A cross-level interaction occurs when a variable measured at level-one affects the relationship between a variable measured at another level and the outcome[93]. Cross-level interactions are only explored when the slope of a level-one parameter is found to significantly vary across level-two units[94]. Third, HLM allows the researcher to account for repeated measures in individuals, or individual growth trajectories. In this scenario, level-one becomes the repeated-observations model and level-two is the person-level model[93].

The Basic Structure of a Longitudinal Two-Level Model

The Unconditional Model

Although most multi-level models aim to describe the change in the outcome over time, the unconditional means model is the first model that the researcher should fit, and is absent of predictors at every level[95]. The primary aim of fitting the unconditional model is to partition the outcome variation into the within-person variance (σ^2) and the between-person variance (τ_{00})[95]. Significance testing of these variances will determine whether there is adequate variation at a particular level to justify further analyses. If each variance component is significantly different than zero, the researcher will aim to explain this variation through the introduction of predictors at each submodel, as described below.

The Level-one Conditional Model

The level-one component of a longitudinal multi-level model can be thought of as the individual growth model; this model shows the expected change in the outcome of interest for a single person during the period of observation[95]. In its simplest form this model can be written as:

$Y_{ij} = \pi_{oi} + \pi_{1i}(\text{Time})_{ij} + e_{ij}$

Where π_{oi} represents individual i's true initial status, or the value of outcome, Y_{ij}, when $Time_{ij} = 0$

π_{1i} = individual i's true rate of change during the observation of study

e_{ij} = deviation of individual i's observed outcome at time j from the predicted outcome; assumed to be normally distributed with a mean of zero, and a constant variance, σ^2.

It should be noted that level-one residuals in longitudinal data sets may not meet these assumptions. Multi-level modeling accounts for the possibility that errors may be autocorrelated or heteroscedastic over occasions within person[95]. In multi-level models, the level-two residuals allow individual i's trajectory to differ from the population average change trajectory. Thus, as individual i's predicted trajectory is a composite of level-one and level-two submodels and their respective intercepts and slopes, individual i's residuals are also a composite of the level-one and level-two errors[95].

Composite residual = $[\mu_{oi} + \mu_{1i}(Time)_{ij} + e_{ij}]$

The Level-two Conditional Model

The level-two submodel describes the impact of group characteristics on individual i's growth trajectory. An individual linear growth model at level-one requires two level-two submodels: one for the intercept and one for the slope. Each of these models will attribute changes in π_{oi} and π_{1i} to the specified level-two predictor (e.g. school-based nutrition intervention). Therefore, the level-two submodel with one level-two predictor (NUTRprogram) can be written as:

$\pi_{oi} = \gamma_{00} + \gamma_{01}(NUTRprogram)_i + \mu_{oi}$

$\pi_{1i} = \gamma_{10} + \gamma_{11}(NUTRprogram)_i + \mu_{1i}$

Where γ_{00} = the population average of the level-one intercepts, when the level-two predictor = 0

γ_{01} = describes how the population average changes for every one-unit increase in the level-two predictor

γ_{10} = the population average of the level-one slopes, for individuals with a level-two predictor value = 0

γ_{11} = population average difference in the level-one slope for a one unit increase in the level-two predictor

μ_{oi} and μ_{1i} = level-two residuals that represent child i's deviation between his/her initial status rate of change and the population average intercept and slope when the level-two predictor = 0; assumed to be bivariate normally distributed, with a mean of zero, and unknown variances τ_{00} and τ_{11}.

HLM with a Binary Outcome

HLM is the appropriate technique when 1) the expected outcome at each level is represented as a linear function of the regression coefficients and 2) the random effects at each level are normally distributed[93]. These assumptions are generally acceptable when the outcome variable is continuous. However, there are cases in which these assumptions are clearly violated. Binary outcomes (presence of disease yes=1, no=0; individual attended therapy session yes=1, no=0, etc.) require a special case of HLM for three reasons: 1) the predicted values of Y_{ijk} are constrained to values between zero and one, 2) the level one random effect can take on only one of two values and is therefore not normally distributed, and 3) the level one random effect does not meet the assumption of constant variance[93].

Therefore, in cases where the outcome is binary, the level one model will consist of three parts: 1) the sampling model, 2) the link function, and 3) the structural model. For the purposes of this dissertation, we will consider a Bernoulli sampling model, a logit link function, and a linear structural model; notation will follow that of Raudenbush and Bryk[93]. The sampling model (for a two-level model) can be written as follows:

$Y_{ij} \mid \varphi_{ij} \sim B(m_{ij,} \varphi_{ij})$

Y_{ij} is binomially distributed and is defined as the number of "successes" in m_{ij} trials; φ_{ij} is the probability of success on each trial. When $m_{ij} = 1$, Y_{ij} is a binary variable, taking on values of 0-1. When the level one sampling model is binomial, the most common link function is the logit link[93]:

$n_{ij} = \log (\varphi_{ij} / 1-\varphi_{ij})$

where n_{ij} is the log of the odds of success. For example, if the probability of "success" is 0.5, then the odds of success are (0.5/1-0.5)=1 and log(1)=0. The transformed predicted value (n_{ij}) is then related to the predictors of the model, using the following structural model:

$n_{ij} = \log (\varphi_{ij} / 1-\varphi_{ij}) = ß_{oj} + ß_{1j}(X_{1j}) + \mu_{oj}$

where $ß_{oj}$ is the intercept, $ß_{1j}$ is the slope associated with the level one predictor, X_{ij}, and μ_{oj} is the random effect associated with the level one model.

Determination of Fixed and Random Effects

In the specification of a multi-level model, the researcher must make decisions about the identification of intercepts and slopes as either fixed or random. A "fixed" variable is defined as one that is assumed to be measured without error, while a "random" variable is assumed to take on values that are drawn from a larger population of values and is therefore, representative of all possible values in the population[93]. In multi-level regression models, the level-one and level-two predictors are typically assumed to be fixed, while the level-one intercepts and slopes can be defined as either fixed or random by the researcher.

A random-intercepts model denotes a multi-level model that allows the intercept to vary across level-two units, but assigns the same slope to each of these units. In this type of model each student's intercept is allowed to vary from the sample average and is defined as the predicted probability of participation, controlling for the level-two explanatory variables, on a day when zero LF entrées are offered. It is expected that a given student will vary in his/her average participation in school lunch and a random-intercepts model allows for an individual student to differ in this "baseline" value. However, the relationship between day score (the level-one explanatory variable) and participation (the outcome of interest) is the same for every student in this model and is not allowed to vary. In the current study, a fixed slope would assume that the effect of day score on the log odds of participation or LF entrée selection is the same for all SES groups, ethnicities, etc. This dissertation will, instead, initially test a random-intercepts-and-slopes model.

A random-intercepts-and-slopes model allows the relationship between the level-one explanatory variable (day score) and the response (participation or LF entrée selection) to be different for each student (level-two unit). An illustration of this concept is provided in Figure 11. This model now contains a u_1x_1 term and u_1 is different for each student, so that mathematically this coefficient is now unique for each level-two unit. For the purposes of this dissertation, both a random-intercepts and a random-intercepts-and-slopes model will be tested for their fit to the data. Model fit will be determined using the proportion of variance explained (PVE) in each outcome, due to the absence of deviance scores in logistic multi-level modeling. A failure of the model to converge will inherently suggest a poor fit of that model to the data. All random effects will be estimated using Restricted Maximum Likelihood (REML), which removes the effects of the fixed variables before estimating the random components of the model[96]. Results will be reported as predicted probabilities, which are obtained from the log odds using the following formula, where B0, B1, and B2 are the intercept and coefficient values obtained from the HLM model output.

$$p = \frac{odds}{1+odds} = \frac{e^{(b_0+b_1x_1+b_2x_2)}}{1+e^{(b_0+b_1x_1+b_2x_2)}}$$

Figure 11: Random Slope Model Illustration

Fixed Slope Model	Random Slope Model
$Y_{ij} = B_o + B_1X_{1ij} + u_{oj} + r_{1j}$	$Y_{ij} = B_o + (B_1 + u_{1j})X_{1ij} + u_{oj} + r_{1j}$ $Y_{ij} = B_o + B_1X_{ij} + u_{oj} + u_1X_{1ij} + r_{1j}$

Appendix B: Definition of Level-one and Level-two Predictors

Day Score – A level-one categorical predictor that describes the number of LF entrées offered at school lunch on a given day. Values range from 0-2 (0 = no LF entrées offered, 1 = one LF entrée offered, 2 = 2 LF entrées offered). Three entrées were offered at school lunch each day of the school year.

Child SES – a level two predictor describing if the child was on free or reduced lunch (0) or paid for lunch (1).

Gender - a level-two predictor describing if the child was female (0) or male (1).

Grade – a level-two predictor describing if the child was in first (0), second (1), third (2), fourth (3), or fifth (4) grade.

Ethnicity – a level-two predictor dummy coded to contrast African American students, Hispanic students, and students of "other" ethnicity with white students. Three terms were included in each model: Other (if =1, compares Asian, Native American, and Pacific Islander students to white students), Black (if =1, compares Black students to white students), and Hispanic (if=1, compares Hispanic students to white students). Students of Asian, American Indian, and Pacific Islander origin were collapsed into one category (Other) due to the small percentage of total students in each of these racial categories.

Appendix C: Random Intercept Model for LF Entrée Selection

Table 6: The Random Intercepts Model for LF Entrée Selection

Level 1 Model
Prob(Y=1|B) = P log[P/(1-P)] = P0 + P1*(DayScore)
Level 2 Model
P0 = P0 = B00 + B01*(SEX) + B02*(GRADE) + B03*(SES) + B04*(OTHER) + B05*(BLACK) + B06*(HISPANIC) + r0 P1 = B10
Mixed Model
eta = B00 + B01*SEX + B02*GRADE + B03*SES + B04*OTHER + B05*BLACK + B06*HISPANIC + B10*DayScore + r0

Figure 12: Gender does not Impact LF Entrée Selection

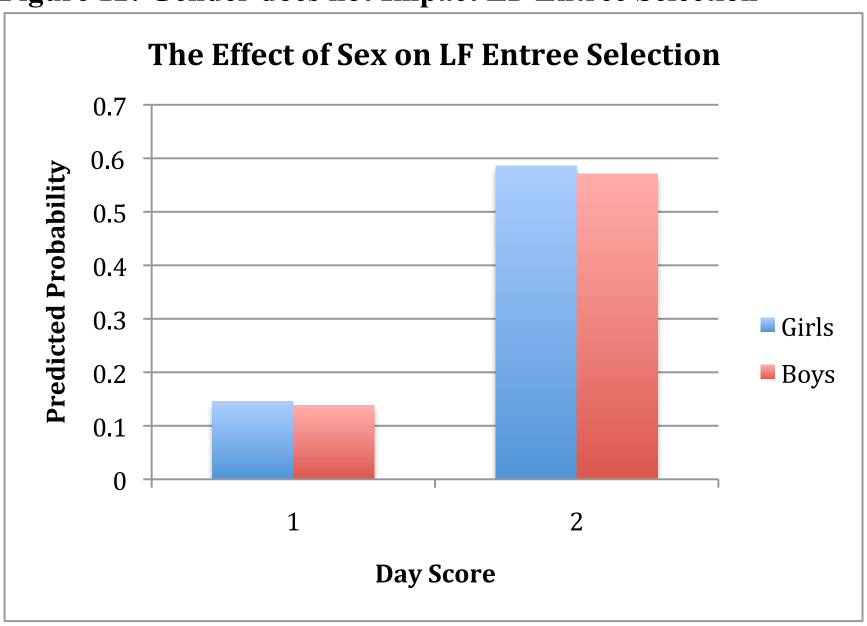


Figure 13: SES does not Impact LF Entrée Selection

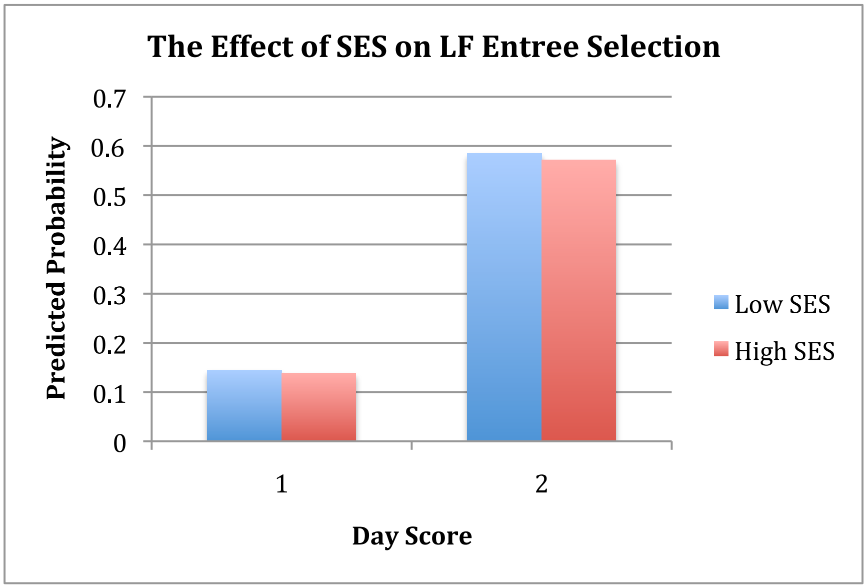
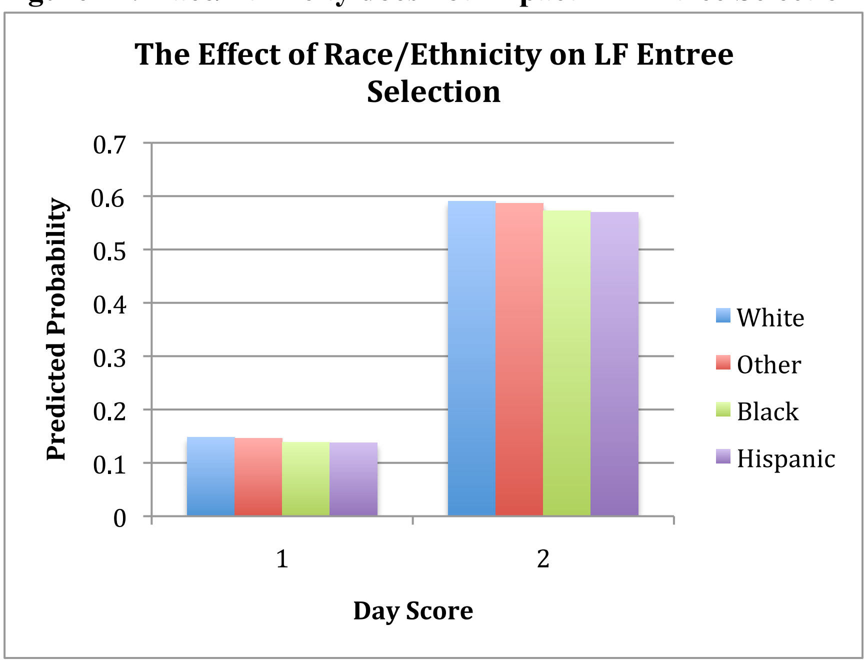


Figure 14: Race/Ethnicity does not Impact LF Entrée Selection



References

1. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011-2012. *JAMA.* 2014;311(8):806-814.
2. Vernarelli JA, Mitchell DC, Hartman TJ, Rolls BJ. Dietary energy density is associated with body weight status and vegetable intake in US children. *The Journal of nutrition.* 2011;141(12):2204-2210.
3. Roseman MG, Riddell MC, Haynes JN. A content analysis of kindergarten-12th grade school-based nutrition interventions: taking advantage of past learning. *Journal of nutrition education and behavior.* 2011;43(1):2-18.
4. Wang D, Stewart D. The implementation and effectiveness of school-based nutrition promotion programmes using a health-promoting schools approach: a systematic review. *Public health nutrition.* 2013;16(06):1082-1100.
5. Bastian A. The future of public health nutrition: a critical policy analysis of Eat Well Australia. *Australian and New Zealand journal of public health.* 2011;35(2):111-116.
6. Wansink B, Sobal J. Mindless Eating The 200 Daily Food Decisions We Overlook. *Environment and Behavior.* 2007;39(1):106-123.
7. Wansink B, Just DR, Hanks AS, Smith LE. Pre-sliced fruit in school cafeterias: Children's selection and intake. *American journal of preventive medicine.* 2013;44(5):477-480.
8. Hanks AS, Just DR, Smith LE, Wansink B. Healthy convenience: nudging students toward healthier choices in the lunchroom. *Journal of Public Health.* 2012;34(3):370-376.
9. Department of Agriculture. Nutrition standards in the National School Lunch and School Breakfast Programs: final rule. http://www.gpo.gov/fdsys/pkg/FR-2012-01-26/pdf/2012-1010.pdf. Accessed October 27, 2014.
10. Reedy J, Krebs-Smith SM. Dietary sources of energy, solid fats, and added sugars among children and adolescents in the United States. *Journal of the American Dietetic Association.* 2010;110(10):1477-1484.
11. Wang YC, Bleich SN, Gortmaker SL. Increasing caloric contribution from sugar-sweetened beverages and 100% fruit juices among US children and adolescents, 1988,2004. *Pediatrics.* 2008;121(6):e1604-e1614.
12. Piernas C, Popkin BM. Trends in snacking among US children. *Health Affairs.* 2010;29(3):398-404.
13. Bowman SA, Gortmaker SL, Ebbeling CB, Pereira MA, Ludwig DS. Effects of fast-food consumption on energy intake and diet quality among children in a national household survey. *Pediatrics.* 2004;113(1):112-118.
14. Guenther PM, Dodd KW, Reedy J, Krebs-Smith SM. Most Americans eat much less than recommended amounts of fruits and vegetables. *Journal of the American Dietetic Association.* 2006;106(9):1371-1379.
15. Drewnowski A, Darmon N. The economics of obesity: dietary energy density and energy cost. *The American journal of clinical nutrition.* 2005;82(1):265S-273S.
16. Hanson MD, Chen E. Socioeconomic status and health behaviors in adolescence: a review of the literature. *Journal of behavioral medicine.* 2007;30(3):263-285.

17. Xie B, Gilliland FD, Li Y-F, Rockett HR. Effects of ethnicity, family income, and education on dietary intake among adolescents. *Preventive medicine.* 2003;36(1):30-40.
18. Dubowitz T, Heron M, Bird CE, et al. Neighborhood socioeconomic status and fruit and vegetable intake among whites, blacks, and Mexican Americans in the United States. *The American journal of clinical nutrition.* 2008;87(6):1883-1891.
19. Rasmussen M, Krolner R, Klepp K-I, et al. Determinants of fruit and vegetable consumption among children and adolescents: a review of the literature. Part I: quantitative studies. *International Journal of Behavioral Nutrition and Physical Activity.* 2006;3(1):22.
20. Lytle LA, Seifert S, Greenstein J, McGovern P. How do children's eating patterns and food choices change over time? Results from a cohort study. *American Journal of Health Promotion.* 2000;14(4):222-228.
21. Cooke LJ, Wardle J. Age and gender differences in children's food preferences. *British Journal of Nutrition.* 2005;93(05):741-746.
22. Gugger C, Bidwai S, Joshi N, Holschuh N, Albertson A. Vegetable consumption and associated nutrient intakes in the United States: results from NHANES 2009-10 and the new USDA Food Patterns Equivalents Database (1023.5). *The FASEB Journal.* 2014;28(1 Supplement):1023.1025.
23. Murphy S, Castillo R, Martorell R, Mendoza F. An evaluation of food group intakes by Mexican-American children. *Journal of the American Dietetic Association.* 1990;90(3):388-393.
24. Erinosho TO, Berrigan D, Thompson FE, Moser RP, Nebeling LC, Yaroch AL. Dietary Intakes of Preschool-Aged Children in Relation to Caregivers. Race/Ethnicity, Acculturation, and Demographic Characteristics: Results from the 2007 California Health Interview Survey. *Maternal and child health journal.* 2012;16(9):1844-1853.
25. Lind C, Mirchandani GG, Castrucci BC, Chavez N, Handler A, Hoelscher DM. The Effects of Acculturation on Healthy Lifestyle Characteristics Among Hispanic Fourth. Grade Children in Texas Public Schools, 2004-2005. *Journal of School Health.* 2012;82(4):166-174.
26. Salinas JJ, Shah MS, Gay JL, et al. Socioeconomic and Cultural County-level Factors Associated with Race/Ethnic Differences in Body Mass Index in 4th Grade Students in Texas. *Journal of Applied Research on Children: Informing Policy for Children at Risk.* 2013;4(2):7.
27. Rennie KL, Johnson L, Jebb SA. Behavioural determinants of obesity. *Best Practice & Research Clinical Endocrinology & Metabolism.* 2005;19(3):343-358.
28. Greenwald P, Clifford C, Milner J. Diet and cancer prevention. *European Journal of Cancer.* 2001;37(8):948-965.
29. Ludwig DS, Pereira MA, Kroenke CH, et al. Dietary fiber, weight gain, and cardiovascular disease risk factors in young adults. *JAMA.* 1999;282(16):1539-1546.
30. Oh K, Hu FB, Manson JE, Stampfer MJ, Willett WC. Dietary fat intake and risk of coronary heart disease in women: 20 years of follow-up of the nurses' health study. *American journal of epidemiology.* 2005;161(7):672-679.
31. Greer FR, Krebs NF. Optimizing bone health and calcium intakes of infants, children, and adolescents. *Pediatrics.* 2006;117(2):578-585.

32. Forman JP, Stampfer MJ, Curhan GC. Diet and lifestyle risk factors associated with incident hypertension in women. *JAMA.* 2009;302(4):401-411.
33. Gillis L, Kennedy L, Gillis A, Bar-Or O. Relationship between juvenile obesity, dietary energy and fat intake and physical activity. *International journal of obesity and related metabolic disorders: journal of the International Association for the Study of Obesity.* 2002;26(4):458.
34. Jennings A, Welch A, van Sluijs EM, Griffin SJ, Cassidy An. Diet quality is independently associated with weight status in children aged 9-10 years. *The Journal of nutrition.* 2011;141(3):453-459.
35. Kranz S, Findeis JL, Shrestha SS. Use of the Revised Children's Diet Quality Index to assess preschooler's diet quality, its sociodemographic predictors, and its association with body weight status. *Jornal de pediatria.* 2008;84(1):26-34.
36. Lin B-H, Morrison RM. Higher fruit consumption linked with lower body mass index. *Food review.* 2002;25(3):28-32.
37. Wosje KS, Khoury PR, Claytor RP, et al. Dietary patterns associated with fat and bone mass in young children. *The American journal of clinical nutrition.* 2010;92(2):294-303.
38. Dattilo AM, Birch L, Krebs NF, Lake A, Taveras EM, Saavedra JM. Need for early interventions in the prevention of pediatric overweight: a review and upcoming directions. *Journal of obesity.* 2012;2012.
39. Doll R, Peto R. The causes of cancer: quantitative estimates of avoidable risks of cancer in the United States today. *Journal of the National Cancer Institute.* 1981;66(6):1192-1308.
40. Williams MT, Hord NG. The role of dietary factors in cancer prevention: beyond fruits and vegetables. *Nutrition in clinical practice.* 2005;20(4):451-459.
41. Key TJ, Schatzkin A, Willett WC, Allen NE, Spencer EA, Travis RC. Diet, nutrition and the prevention of cancer. *Public health nutrition.* 2004;7(1a):187-200.
42. Cutler GJ, Flood A, Hannan P, Neumark-Sztainer D. Major patterns of dietary intake in adolescents and their stability over time. *The Journal of Nutrition.* 2009;139(2):323.
43. Kelder SH, Perry CL, Klepp KI, Lytle LL. Longitudinal tracking of adolescent smoking, physical activity, and food choice behaviors. *American Journal of Public Health.* 1994;84(7):1121.
44. Ritchie LD, Spector P, Stevens MJ, et al. Dietary patterns in adolescence are related to adiposity in young adulthood in black and white females. *The Journal of Nutrition.* 2007;137(2):399.
45. Fox MK, Dodd AH, Wilson A, Gleason PM. Association between school food environment and practices and body mass index of US public school children. *Journal of the American Dietetic Association.* 2009;109(2):S108-S117.
46. Sharma M. School-based interventions for childhood and adolescent obesity. *Obesity Reviews.* 2006;7(3):261-269.
47. Jaime PC, Lock K. Do school based food and nutrition policies improve diet and reduce obesity? *Preventive medicine.* 2009;48(1):45-53.
48. French SA, Stables G. Environmental interventions to promote vegetable and fruit consumption among youth in school settings. *Preventive medicine.* 2003;37(6):593-610.

49. Caballero B, Clay T, Davis SM, et al. Pathways: a school-based, randomized controlled trial for the prevention of obesity in American Indian schoolchildren. *The American journal of clinical nutrition.* 2003;78(5):1030-1038.
50. Williamson DA, Copeland AL, Anton SD, et al. Wise Mind Project: A School-based Environmental Approach for Preventing Weight Gain in Children. *Obesity.* 2007;15(4):906-917.
51. Reynolds KD, Franklin FA, Leviton LC, et al. Methods, results, and lessons learned from process evaluation of the high 5 school-based nutrition intervention. *Health education & behavior.* 2000;27(2):177-186.
52. Burgess-Champoux TL, Chan HW, Rosen R, Marquart L, Reicks M. Healthy whole-grain choices for children and parents: a multi-component school-based pilot intervention. *Public health nutrition.* 2008;11(08):849-859.
53. Foster GD, Sherman S, Borradaile KE, et al. A policy-based school intervention to prevent overweight and obesity. *Pediatrics.* 2008;121(4):e794-e802.
54. Perry CL, Bishop DB, Taylor GL, et al. A randomized school trial of environmental strategies to encourage fruit and vegetable consumption among children. *Health education & behavior.* 2004;31(1):65-76.
55. Folta SC, Goldberg JP, Economos C, Bell R, Landers S, Hyatt R. Assessing the use of school public address systems to deliver nutrition messages to children: Shape up Somerville,Audio adventures. *Journal of School Health.* 2006;76(9):459-464.
56. Reynolds KD, Franklin FA, Binkley D, et al. Increasing the fruit and vegetable consumption of fourth-graders: results from the high 5 project. *Preventive medicine.* 2000;30(4):309-319.
57. Folta SC, Goldberg JP, Economos C, Bell R, Landers S, Hyatt R. Assessing the use of school public address systems to deliver nutrition messages to children: Shape up Somerville,Audio adventures. *Journal of School Health.* 2006;76(9):459-464.
58. Epstein LH, Salvy SJ, Carr KA, Dearing KK, Bickel WK. Food reinforcement, delay discounting and obesity. *Physiology & behavior.* 2010;100(5):438-445.
59. Epstein LH, Leddy JJ, Temple JL, Faith MS. Food reinforcement and eating: a multilevel analysis. *Psychological bulletin.* 2007;133(5):884.
60. Vuchinich RE, Tucker JA. Contributions from behavioral theories of choice to an analysis of alcohol abuse. *Journal of Abnormal Psychology.* 1988;97(2):181.
61. Bickel WK, Madden GJ, Petry NM. The price of change: The behavioral economics of drug dependence. *Behavior Therapy.* 1998;29(4):545-565.
62. Madden GJ, Petry NM, Johnson PS. Pathological gamblers discount probabilistic rewards less steeply than matched controls. *Experimental and clinical psychopharmacology.* 2009;17(5):283.
63. Ledgerwood DM, Alessi SM, Phoenix N, Petry NM. Behavioral assessment of impulsivity in pathological gamblers with and without substance use disorder histories versus healthy controls. *Drug and alcohol dependence.* 2009;105(1):89-96.
64. Goldfield GS, Epstein LH. Can fruits and vegetables and activities substitute for snack foods? *Health Psychology.* 2002;21(3):299.
65. Bonato DP, Boland FJ. Delay of gratification in obese children. *Addictive behaviors.* 1983;8(1):71-74.

66. Francis LA, Susman EJ. Self-regulation and rapid weight gain in children from age 3 to 12 years. *Archives of Pediatrics & Adolescent Medicine.* 2009;163(4):297-302.
67. Seeyave DM, Coleman S, Appugliese D, et al. Ability to delay gratification at age 4 years and risk of overweight at age 11 years. *Archives of Pediatrics & Adolescent Medicine.* 2009;163(4):303-308.
68. Olstad DL, Goonewardene LA, McCargar LJ, Raine KD. Choosing healthier foods in recreational sports settings: a mixed methods investigation of the impact of nudging and an economic incentive. *International Journal of Behavioral Nutrition and Physical Activity.* 2014;11(1):6.
69. Hakim SM, Meissen G. Increasing Consumption of Fruits and Vegetables in the School Cafeteria: The Influence of Active Choice. *Journal of health care for the poor and underserved.* 2013;24(2):145-157.
70. Korinek EV, Bartholomew JB, Jowers EM, Latimer LA. Fruit and vegetable exposure in children is linked to the selection of a wider variety of healthy foods at school. *Maternal & child nutrition.* 2013.
71. Bartholomew JB, Jowers EM. Increasing frequency of lower-fat entrees offered at school lunch: an environmental change strategy to increase healthful selections. *Journal of the American Dietetic Association.* 2006;106(2):248-252.
72. DiSogra L, Glanz K, Rogers T. Working with community organizations for nutrition intervention. *Health Education Research.* 1990;5(4):459-465.
73. Lucarelli JF, Alaimo K, Mang E, et al. Facilitators to Promoting Health in Schools: Is School Health Climate the Key? *Journal of School Health.* 2014;84(2):133-140.
74. Wansink B. Convenient, Attractive, and Normative: The CAN Approach to Making Children Slim by Design. *Childhood Obesity.* 2013;9(4):277-278.
75. Luepker R, Perry C, Osganian V, et al. The child and adolescent trial for cardiovascular health (CATCH). *The Journal of Nutritional Biochemistry.* 1998;9(9):525-534.
76. Dietary guidelines for Americans 2010. *US Department of Agriculture, 7th edition. Washington (DC): US Government Printing Office.* 2010.
77. WebSMARTT. (2014). Retrieved June 18, from http://www.heartlandpaymentsystems.com/School-Solutions/School-Nutrition-Solutions/Current-Customers/WebSMARTT/Modules/Point-of-Sale. .
78. Cho H, Nadow MZ. Understanding barriers to implementing quality lunch and nutrition education. *Journal of Community Health.* 2004;29(5):421-435.
79. Gleason PM, Suitor CW. Eating at school: how the National School Lunch Program affects children's diets. *American Journal of Agricultural Economics.* 2003;85(4):1047-1061.
80. U.S. Department of Agriculture. Nutrition standards in the national school lunch and school breakfast programs. *Federal Register.* 2012;77(17):4088-4167.
81. Marcus C, Nyberg G, Nordenfelt A, Karpmyr M, Kowalski J, Ekelund U. A 4-year, cluster-randomized, controlled childhood obesity prevention study: STOPP. *International Journal of Obesity.* 2009;33(4):408-417.
82. Siega-Riz AM, El Ghormli L, Mobley C, et al. The effects of the HEALTHY study intervention on middle school student dietary intakes. *Int J Behav Nutr Phys Act.* 2011;8(7).

83. Cohen JF, Rimm EB, Bryn Austin S, Hyatt RR, Kraak VI, Economos CD. A Food Service Intervention Improves Whole Grain Access at Lunch in Rural Elementary Schools. *Journal of School Health.* 2014;84(3):212-219.
84. Kim SA, Moore LV, Galuska D, et al. Vital signs: fruit and vegetable intake among children—United States, 2003–2010. *MMWR Morb Mortal Wkly Rep.* 2014;63(31):671-676.
85. Briefel RR, Crepinsek MK, Cabili C, Wilson A, Gleason PM. School food environments and practices affect dietary behaviors of US public school children. *Journal of the American Dietetic Association.* 2009;109(2):S91-S107.
86. Child and Adult Care Food Program: Amendments Related to the Healthy, Hunger-Free Kids Act of 2010. *7 C.F.R. Part 226 RIN 0584-AE12.* 2012.
87. Korinek EV, Bartholomew JB, and Pasch KE. The effect of school lunch menu composition on participation rates and low-fat food selection in elementary children. *Abstract submitted to the annual meeting of the Society of Behavioral Medicine, Philadelphia, PA.* 2014
88. Schiffman SS, Graham BG, Sattely-Miller EA, Peterson-Dancy M. Elevated and sustained desire for sweet taste in African-Americans: a potential factor in the development of obesity. *Nutrition.* 2000;16(10):886-893.
89. Kaiser LL, Melgar-Quinonez HR, Lamp CL, Johns MC, Harwood JO. Acculturation of Mexican-American mothers influences child feeding strategies. *Journal of the American Dietetic Association.* 2001;101(5):542-547.
90. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of obesity and trends in body mass index among US children and adolescents, 1999-2010. *JAMA: The Journal of the American Medical Association.* 2012;307(5):483-490.
91. Story M, Kaphingst KM, Robinson-O'Brien R, Glanz K. Creating healthy food and eating environments: policy and environmental approaches. *Annu. Rev. Public Health.* 2008;29:253-272.
92. McCoach DB. Hierarchical linear modeling. *The reviewer's guide to quantitative methods in the social sciences.* 2010:123-140.
93. Raudenbush SW, Bryk AS. *Hierarchical linear models: Applications and data analysis methods.* Vol 1: Sage; 2002.
94. Davison ML, Kwak N, Seo YS, Choi J. Using hierarchical linear models to examine moderator effects: Person-by-organization interactions. *Organizational Research Methods.* 2002;5(3):231-254.
95. Singer JD, Willett JB. *Applied longitudinal data analysis: Modeling change and event occurrence.* Oxford university press; 2003.
96. Kreft IG & Leeuw Jd. *Introducing multilevel modeling.* Sage; 1998.