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Understanding Out-of-Home Food Environment, Family Restaurant Choices, and Childhood Obesity with an Agent-Based Huff Model

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Abstract: Out-of-home eating plays an increasingly important role in the American diet and weight. This research studied out-of-home food environment and restaurant choices in one rural county of eastern Alabama, United States, and examined the impact on African American children's weight status. A mixed methods approach was used in this study. Questionnaires were collected for 613 African American children at all four public elementary schools in the county. The healthfulness of restaurants was assessed with the Nutrition Environment Measures Survey-Restaurant (NEMS-R). An agent-based model integrated with Huff's model was developed in order to examine family dining patterns with consideration for individual and community socio-demographics; restaurant location, size, and healthfulness; and the spatial dynamics between consumers and food retailers. We found that this model performed well, as evidenced by validation with the 2013–2014 National Health and Nutrition Examination Survey (p, 0.54–0.96), and by comparison with the original Huff model. Frequency of dining at low-quality full-service restaurants ($r = 0.084$; $p < 0.05$) was associated with rural children's body mass index (BMI) percentile. These findings may increase public awareness of the importance of family restaurant choices as well as the potential unhealthiness of full-service restaurants.

Keywords: out-of-home food environment; family restaurant choices; childhood obesity; rural African American; Agent-based Huff model

1. Introduction

The prevalence of childhood obesity has increased markedly over the past several decades [1], and consumption of food away from the home plays an increasingly important role in the American diet and weight [2–4]. In 2010, the average expenditure of a family on dining out was over $2500 [5,6]. Spending on food away from the home accounted for 25.9% of total expenditure on food in 1970, rising sharply to 43.1% of total expenditure in 2012 [4]. For children and adolescents aged 2–18 years, fast food and full-service restaurants contributed 2% and 1% of daily energy intake, respectively, from 1977 to 1978, and up to 13% and 5%, respectively, from 2003 to 2006 [3]. Previous studies have found associations between children's food consumption away from the home and higher total energy intake, lower dietary quality, and a greater risk of being overweight or obese [2,3,7,8]. Naturally, concerns have risen over the impacts of the out-of-home food environment and family restaurant choices on children's diet and weight [9,10].

There is a vast body of literature documenting the relationship between food environment and consumer dining choices [11,12]. As consumers, families often make dining decisions by comprehensively considering several restaurant criteria, such as food quality, service quality, accessibility, size, price, and promotions [11,13]. Nowadays, parents are increasingly aware of the influence of food nutrition, healthfulness, and safety on children's health [13,14]. However, restaurant choice includes consideration of much more than merely obtaining nutrients and services needed to sustain life [15]. Family restaurant choices are also intertwined with socioeconomic, cultural, and environmental factors at multiple levels [3,15,16]. Socioeconomic disadvantages and uneven food environments are both barriers to healthy dining for rural minority children due to their social economic status (SES) and community environments [16,17]. It should not be surprising that families' restaurant choices are closely associated with their income, education, and race because of the resulting financial ability, nutritional knowledge, and food culture [18,19]. Neighborhoods of low SES are more likely to be exposed to fast food restaurants than are middle to higher SES neighborhoods [20]. The association between out-of-home eating and poor diet impacts children and adolescents in all social and economic classes, but this relationship most strongly affects children from lower SES neighborhoods [21,22].

Consumer decision-making with regard to dining is a complex process related to market dynamics and competition among food retailers [23]. Spatial interaction models have been widely used to understand consumers' shopping choices and to examine the dynamics of retail competition [24,25]. The most influential spatial interaction model, Huff's model, estimates the likelihood that a consumer will patronize a certain store among all potential competitors [26]. The probability is positively related to the attractiveness of the store and inversely related to the distance between the consumer and the store [27]. Past research on the attractiveness of retail stores has highlighted the importance of store size [27,28], agglomeration effect [24], and physical location [27,29,30]. Food quality and nutrition are also important aspects of store attractiveness influencing consumer patronage [30].

Consumers' choices are determined by the interactions of sociodemographic, locational, environmental, and nutritional factors, which the spatial interaction model alone is not able to model and describe. However, the agent-based model, a systems science approach, offers a robust tool for simulating consumer choices [23,31]. It is a powerful simulation technique able to model complex processes involving multiple dynamic interactions between people and their environments [32,33]. Thus far, little research has used systems science methodology to examine dining choices [31,34]. Extant agent-based simulations of consumer dietary behaviors are mainly performed in a gridded space with virtual agents, such as in grocery shopping simulations [35], racial segregation and diet [36], and convenience store footfalls [37]. The integration of this approach with empirical data and a spatial interaction model provides new insight into family restaurant choice with a broader scope.

This paper addresses two objectives. First, this study intends to understand the restaurant choices of children and families with consideration for sociodemographic, locational, environmental, and nutritional factors using an agent-based Huff model. Second, this paper focuses on underserved rural African American children. Most existing research has investigated urban populations in the U.S., resulting in limited knowledge of rural families' dining patterns [38,39]. How are family restaurant choices correlated with childhood obesity in rural communities? This paper examines the impact of out-of-home food environments as well as family dining patterns on childhood obesity in one rural county of eastern Alabama, U.S.

2. Materials and Methods

2.1. Analytical Framework

This research was built on an analytical framework integrating socio-ecological models [40] and spatial interaction theory [27,41] in order to better explain the impact of social and environmental disparities on family restaurant choices and childhood obesity (Figure 1). The core premise of socioecological models is that individual behaviors and health are shaped by various factors at multiple levels [40,42]. Individuals' behaviors are affected not only by biological and psychological characteristics, but also by their surrounding physical and social environments, which are themselves influenced by broader socioeconomic and policy conditions as well as general beliefs and attitudes [40,43]. These influences interact across multiple levels to affect specific health behaviors at several stages [42].

Previous studies have developed conceptual frameworks based on socio-ecological models in an effort to explain food environments and the dynamics among the many factors that influence diet [31,44]. Li et al. [31] believe that dynamic interactions among the food environment, broad organizational context, and community sociodemographic factors all have great impacts on diet and obesity. Food environment is defined by the type, amount, and quality of food options available as well as the location and accessibility of food sources [16,31,45]. The organizational context influences the food environment at the macro-level. For example, organizational factors include government policies that regulate food location, cost, safety, and supply and also food industry competition and marketing that impacts people's dietary behaviors [31,46]. In addition, community sociodemographic factors, such as income, education, gender, age, and race, play an important role in the interactions between the food environment, organizational context, and dietary behavior [31]. For instance, people living in lower-income, less-educated minority communities are more likely to suffer a lower availability of nutritious food and to have an unhealthy diet [16,31,47].

As a model of competing destinations, Huff's model has been well-accepted for location decision in the retail industry, for example restaurants and food stores [16,29] and shopping centers [24,27]. Huff's model assumes that the spatial interaction between an origin (a family) and a destination (a restaurant) is directly associated with the relative attractiveness of the restaurant compared to all competitors and also inversely proportional to the relative proximity of the restaurant compared to all competing restaurants [24,27]. Other famous choice theories, such as stability in competition [48], the theory of cumulative attraction [49], location-allocation models [50,51], and other discrete models [52], assume that all competing destinations are equally attractive to consumers and therefore consumers would choose the nearest facility [53]. Compared to these theories, Huff's model makes a step forward by estimating the distribution of total buying power among all destinations in a competing environment.

From the multilevel socio-ecological framework [31], we extracted three key components, which can be well-reflected by an agent-based Huff model. The first consideration is food retailers, namely food environment. Consumer's choice is determined by a series of information that influences perceptions of each store [30]. Restaurant attractiveness to consumers is based on judgment of food options and healthfulness [31], store types [45], seating capacity or size [29], and accessibility [29,31]. The second factor to consider is consumers' (family) demographics and the communities where they live. The spatial location of a family greatly determines the food environment and social context to which children are exposed. The individual and community SES and related factors, such as gender, age, race, income, and education levels, are strongly associated with the quality of the surrounding food environment [47] and dietary behaviors. Thirdly, families' restaurant choices are also influenced by the spatial interactions between families and food retailers, as well as competition among food retailers, as estimated by Huff's model.

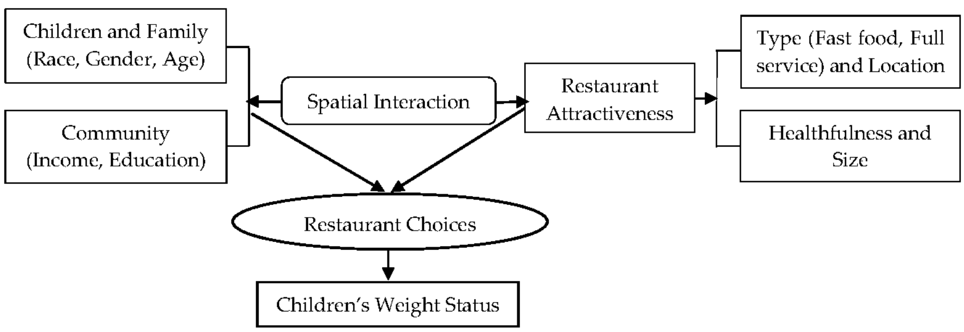

Figure 1. Analytical framework.

2.2. Study Area

The setting for this research is a county in rural Alabama in the Black Belt region. The Black Belt region is located in the southern U.S., extends over an area including Mississippi, Tennessee, Alabama, and Georgia, and has low-income rural African Americans making up a large proportion of the population [16,54]. According to the 2010 census, the county had a population of 21,452. This population was 82.6% African American, 15.5% Caucasian, and 1.9% other races. One of the poorest counties in Alabama, 32.8% of the population and 26.6% of families were in poverty. The median household income was $21,180, which was much lower than that of Alabama as a whole ($43,160) [55].

2.3. Survey Assessment of African American Children

Surveys were conducted at all four public elementary schools in this county in spring 2013. The study was approved by the Institutional Review Board (IRB) at Auburn University. According to our agreement with the IRB, we are not allowed to disclose any identifiable information to the public in any form, including children's own information and names or locations of schools and the county. Invitation letters were sent home with all African American students enrolled in kindergarten through grade five. Effective questionnaires were collected from 613 children with a return rate of over 50%. Surveyed children were aged between 4 and 13 years old. Of the children, 49.1% were girls and 50.9% were boys. The children's ages, genders, and home addresses were collected along with anthropometric measurements of weight, height, and body mass index (BMI). The body weight was recorded to the nearest 0.5 kg using a calibrated standard beam balance scale, and standing body height was measured to the nearest 0.5 centimeters without shoes using a stadiometer. Measured weight and height were used to calculate the BMI percentile based on the Centers for Disease Control and Prevention BMI-for-age growth chart. BMI percentile is the most commonly used measure of children's weight status and growth pattern in the U.S. [16,56]. Children whose BMI was at or above the 95th percentile were defined as obese, while those whose BMI ranked from the 85th to the 95th percentile were defined as overweight, and finally those whose BMI was below the 85th percentile were defined as normal [57].

2.4. Assessment of Restaurants

All 26 restaurants found within the local Yellow Book were included in our analysis, including 11 fast food and 15 full-service restaurants. Fast food restaurants were characterized by minimal service and limited food choices supplied quickly after ordering, while full-service restaurants were defined as having traditional sit-down tables, counters, and booths as well as waiters' services and relatively broad menus open to all ages [58,59]. We browsed the restaurant online menus to collect relevant information. Using the collected information, all restaurants were assessed with the Nutrition Environment Measures Survey-Restaurant (NEMS-R) [58], which evaluates four aspects: the availability of healthful options (AHO), facilitators of healthful eating (FHE), barriers to healthy eating (BHE), and the kid's menu (KM). A score was obtained for each aspect based on the questionnaire and scoring system of the NEMS-R. An overall score reflecting the healthfulness of each restaurant was then obtained by summing the scores for all four aspects. A higher score indicates better restaurant quality. Sample survey questions are summarized in Table 1. For example, the restaurant earns 1 point for the availability of healthful options if it offers one healthy dish/entree, 2 points for having two to four healthy dishes/entrees, and 3 points for five or more healthy choices. For restaurants with nutrition information on their menus, we defined healthy options as entrees with less than 800 calories and less than 30% of calories from fat as well as burgers and sandwiches with less than 650 calories and less than 30% of calories from fat. For those restaurants without nutrition information on their menus, we analyzed the food gradients of entrees, burgers, and sandwiches, and defined those with vegetables and fruits as healthy options. Besides healthfulness, restaurant size was measured with Google Earth in order to determine seat capacity. Size, as a reflection of seat capacity, is an influential spatial factor that interacts with distance [29,60].

Table 1. Sample questions and scoring system of the Nutrition Environment Measures Survey-Restaurant (NEMS-R).

Survey Questions	Scoring (p-Point)
Availability of Healthful Options	
# of healthy dishes/entrees	1 = 1 p; 2–4 = 2 ps; 5 or more = 3 ps.
# of healthy main-dish salads	1 = 1 p; 2–4 = 2 ps; 5 or more = 3 ps.
Facilitators of healthy eating	
Nutrition information on menu or healthy entrees identified on menu	Yes for EITHER = 1 p
Highlighting healthy options or healthy eating encouraged	Yes for EITHER = 1 p
Barriers to healthful eating	
Large portions encouraged	Yes = −1
"All you can eat" or "unlimited" available	Yes = −1
Kid's menu	
1% or nonfat milk availability	Yes = 1
Unhealthy dessert automatic	Yes = −1

2.5. Agent-Based Huff Model

An agent-based Huff model was applied to simulate families' restaurant choices in ArcGIS 10.0. The probability of a family dining at each restaurant in the study area was estimated by using the model to consider three sets of factors: (1) family and community socio-demographics; (2) food retailer accessibility, type, capacity (store size), and healthfulness (score obtained from NEMS-R); and (3) spatial interaction between family and restaurants and competition among restaurants (Table 2). In the model, an agent (family) moves from the home to a certain destination (restaurant) guided by a series of rules determined by multilevel factors (Table 2).

To reflect the consumer's perspective, the model included children's gender and family location as well as community median household income and education level. The children's race was not reflected in the model because all surveyed children were African American and were then all school-age children. The specific rules were designed according to data from African American participants extracted from the dataset of the 2013–2014 National Health and Nutrition Examination Survey (NHANES) collected by the Centers for Disease Control and Prevention [61]. We randomly selected 70% of the surveyed African Americans from the NHANES, whose data was used to construct the rules, and left 30% for model validation.

Regarding destination data, restaurant attractiveness to consumers was represented by a traditional indicator, restaurant size measured by Google Earth, and a new indicator, the overall healthfulness score obtained through the NEMS-R as described in 2.4. Huff's model was used to estimate the spatial interaction between each family (an agent) and a certain restaurant (a destination). Huff's model is represented by the following equation [27]:

$$SI_{ij} = A_i/D_{ij}^{\beta} \Big/ \sum_{j=1}^{n} A_i/D_{ij}^{\beta}$$

where SI_{ij} is the spatial interaction between family i and restaurant j. Here, SI_{ij} is labelled "spatial interaction" instead of "probability" in order to distinguish it from the probability simulated by the new agent-based Huff model. A_j is the attractiveness of restaurant j, indicated by the restaurant size and healthfulness score, respectively. D_{ij} is the street distance from family i to restaurant j, and n is the number of restaurants (n = 26). β is a parameter that represents the effect of distance, which we calibrated with values ranging from 0 to 4 with intervals of 0.5 based on the extant literature on spatial interaction models and the distance decay effect [24]. Given 2 different indicators of restaurant attractiveness and 9 options of β ranging from 0 to 4, 18 values of SI_{ij} were attached to each restaurant, reflecting how likely a family is to interact spatially with each restaurant compared to all competitors.

Using each value of SI_{ij} assigned and the specific rules set up for a family based on sociodemographic factors, each family's restaurant choices were simulated to predict their dining pattern. To verify the reliability of the model, the simulation results were validated using the reserved 30% of the randomly selected data of African American families from the 2013–2014 National Health and Nutrition Examination Survey (NHANES). Since 7-day dining data were collected in the 2013–2014 NHANES, our model was also designed to simulate a family's dining behavior over a 1-week period repeated 100 times. The probabilities associated with fast food and full-service restaurants were calculated for each family, and the average probabilities were obtained for the 100-time (weeks) simulations. Two-sample *t* tests were used to compare the simulated average probabilities of family choice of fast food and full-service restaurants with the national survey data (NHANES).

Table 2. Rules and parameters of the agent-based Huff model.

	Categories	Probability to Fast Food	Probability to Full Service
Children	Boys	70.7%	29.3%
	Girls	69.9%	30.1%
Community (block group)	Education	% of population without high school degree × 71.2% + % of population with high school degree or above × 62.3%	% of population without high school degree × 28.8% + % of population with high school degree or above × 37.7%
	MHHI < Poverty line	75.6%	24.4%
	MHHI > Poverty line	68.5%	31.5%
Restaurants	Fast Food Full-Service	Probability that a family chooses each restaurant estimated by Huff's model	

(Note: 1. MHHI = Median household income. 2. According to the National Health and Nutrition Examination Survey (NHANES) data on African American families, 71.2% of individuals without high school degrees and 62.3% with a high school degree or above went to fast food restaurants, while 28.8% of individuals without high school degrees and 37.7% with a high school degree or above went to full-service restaurants).

2.6. Statistical Analysis

Getis Ord Gi* was run with ArcGIS 10.0 to identify spatial clusters of surveyed children with high or low weight status. The Inverse Distance weight matrix was chosen to evaluate all spatial units in the study area. In addition, Pearson's correlations were run in SPSS 19 to determine the associations between surveyed children's BMI percentile and their families' restaurant choices.

3. Results

3.1. Children's Weight Status and Restaurants' Attractiveness

Table 3 summarizes the sample statistics. Over 26.4% of surveyed children were obese, which is a much higher rate than the 16.9% found at the national level [62]. The obesity rate varied among different age groups, with 18.4% of students aged 4 to 6 identified as obese compared to 27% of students aged 7 to 13 and 31.2% of students aged 10 to 13. The prevalence of obesity in boys (24.9%) was lower than that in girls (28.2%).

Table 3. Sample statistics.

Category	Type	Students	Overweight	Obese	Overweight and Obese
	All	613	15.6%	26.4%	42.1%
Age	4–6	130	15.4%	18.4%	33.8%
	7–9	300	17.3%	27.0%	44.3%
	10–13	183	13.1%	31.2%	44.3%
Gender	Male	301	16.6%	24.9%	41.5%
	Female	312	14.7%	28.2%	42.9%

(Note: sample size = 613; response rate = 50%).

The restaurant information is summarized in Table 4. Figures 2 and 3 compare the distributions of the surveyed students' weight status and restaurant attractiveness (as indicated by restaurant size and healthfulness measured with the NEMS-R). Hot spots of high weight students (z >1.96), as identified by Getis Ord Gi*, were scattered across the entire county. In Figure 2, fast food and full-service restaurants were categorized as either big or small capacity (according to their sizes) using the Jenks Natural Breaks classification in ArcGIS 10.0. In Figure 3, fast food and full-service restaurants were classified as either low or high quality based on their overall healthfulness scores with the Jenks Natural Breaks classification as well. This method was designed to identify the best arrangement of values into different groups through repeated calculations using different breaks in the dataset [63]. The set of cutting points (breaks) with the smallest in-class variance was selected to classify the dataset. We did not observe a correlated pattern between hot spots of high-weight students and their access to either fast food or full-service restaurants regardless of size or food quality.

Table 4. Restaurant characteristics.

ID	Type	Size (sq. ft.)	Healthfulness Score					Average Distance to Family (Meters)
			AHO	FHE	BHE	KM	Total	
0	FS	280	3	1	−1	0	3	8615.77
1	FS	168	4	2	0	2	8	8590.27
2	FS	75	5	2	−1	2	8	8590.26
3	FS	595	7	3	−1	0	9	8654.06
4	FS	766	7	0	0	4	11	11,305.4
5	FS	172	3	0	0	0	3	8880.14
6	FS	345	9	3	0	3	15	19,900.39
7	FS	256	8	2	−1	0	9	19,093.55
8	FS	328	6	1	0	3	10	8738.92
9	FS	189	5	2	0	3	10	8760.47
10	FS	350	9	1	1	2	13	18,815.11
11	FS	133	4	2	0	2	8	21,099.52
12	FS	110	4	2	0	2	8	20,081.69
13	FS	322	6	1	0	3	10	8721.51
14	FS	169	9	1	0	0	10	8653.13
0	FF	203	6	3	−1	5	13	8617.82
1	FF	306	5	3	−2	7	13	8872.48
2	FF	186	5	3	−2	0	6	8531.85
3	FF	198	0	3	−2	0	1	8708.51
4	FF	155	0	0	−1	0	−1	8745.36
5	FF	119	0	0	−1	−1	−2	18,453.77
6	FF	312	7	4	−3	0	8	8687.59
7	FF	240	1	0	0	1	1	18,744.39
8	FF	286	7	4	−3	0	8	23,007.61
9	FF	142	1	0	0	0	1	8578.25
10	FF	217	0	3	−2	0	1	8644.40

(Note: 1. FS = full-service restaurant; FF = fast food restaurant. 2. AHO = the availability of healthful options; FHE = facilitators of healthful eating; BHE = barriers to healthy eating; KM = the kid's menu).

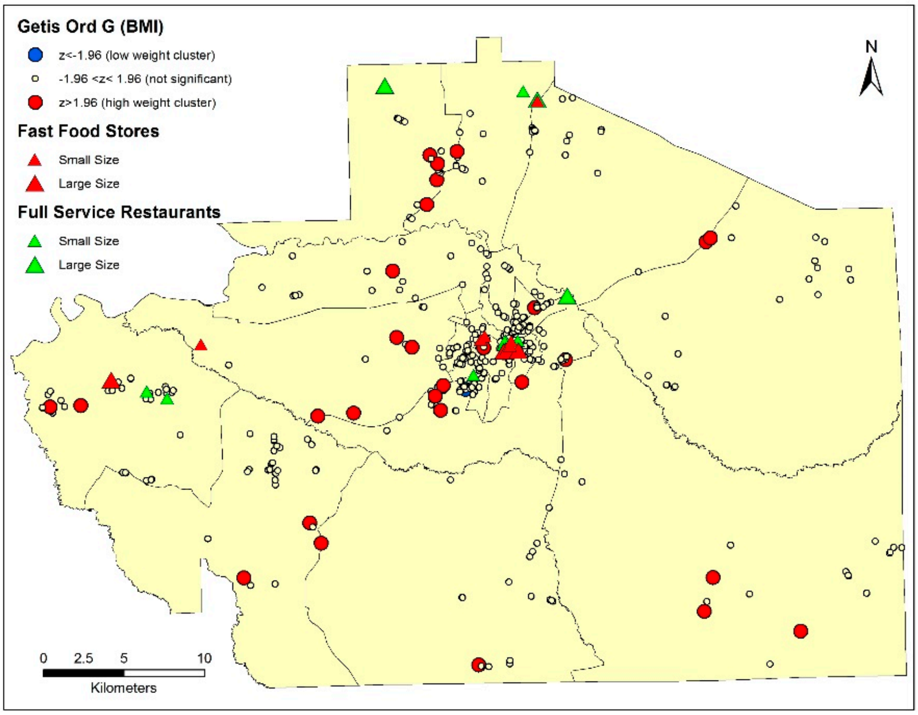

Figure 2. Restaurant size and children's weight status. BMI = body mass index.

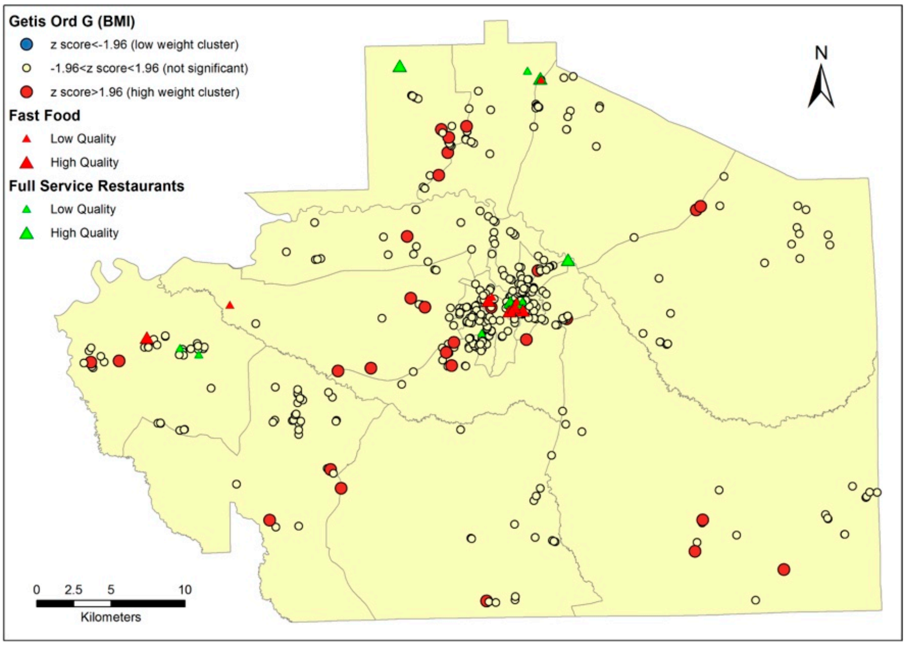

Figure 3. Restaurant healthfulness and children's weight status.

3.2. Agent-Based Huff Model Validation

Simulated family restaurant choices obtained using the agent-based model were validated with the reserved 30% of data from the 2013–2014 National Health and Nutrition Examination Survey (NHANES). Table 5 summarizes the model calibration and validation results. For all surveyed children and families, the simulated probabilities for choice of each fast food and full-service restaurant were calculated with 18 scenarios each, with 2 different A_j values reflecting restaurant attractiveness and 9 β values reflecting the distance decay effect. A two-sample t test was then used to compare the simulated frequencies and the NHANES data. The *p*-values of the two-sample *t* test for all scenarios were over 0.05, indicating that the simulated family dining choices had no significant difference from the national survey data. Therefore, the performance of the agent-based model integrated with Huff's model was reliable for the simulation of family restaurant choices.

Table 5. Agent-based Huff model calibration and validation (*p*-values of a two-sample *t* test).

Distance Beta	Size		Healthfulness	
	Fast Food	Full-Service	Fast Food	Full-Service
Beta = 0	0.76	0.57	0.81	0.55
Beta = 0.5	0.56	0.56	0.71	0.60
Beta = 1	0.63	0.58	0.65	0.59
Beta = 1.5	0.63	0.57	0.79	0.57
Beta = 2	0.64	0.57	0.65	0.59
Beta = 2.5	0.66	0.54	**0.78**	**0.60**
Beta = 3	**0.71**	**0.60**	0.76	0.57
Beta = 3.5	0.74	0.56	0.57	0.57
Beta = 4	0.94	0.54	0.96	0.59

More specifically, when taking traditional restaurant size to indicate attractiveness, *p* values were between 0.56 and 0.94 when comparing simulated probabilities of choosing fast food restaurants with the NHANES data, and from 0.54 to 0.60 while validating the likelihood of choosing full-service restaurants. When using healthfulness as an indication of restaurant attractiveness, *p* values ranged from 0.57 to 0.96 for fast food, and from 0.55 to 0.60 for full-service restaurants. By comprehensively considering all 18 scenarios, the best β value out of 3 was obtained for the size model according to large *p* values for both fast food ($p = 0.71$) and full-service ($p = 0.60$) restaurants. The optimal β value of 2.5 for the healthfulness model was also based on large *p* values for both fast food ($p = 0.78$) and full-service ($p = 0.60$) restaurants. The optimal β values of both models are larger than the default value 2, indicating a very strong distance-decay effect in family restaurant choices in this rural county. The distance-decay parameter reflects the relationship between distance and interaction, which is obtained by calibrating a gravity model [64]. A larger β value indicates a stronger deterrent of distance to interaction [65].

The traditional Huff model was also used to simulate family restaurant choices. Table 6 summarizes the model calibration and validation results. A two-sample *t* test was applied to compare simulated probabilities of choosing fast food or full-service restaurants with the NHANES data. The *p* values for all scenarios were less than 0.01, reflecting a significant difference between the simulated results and the national survey data. Therefore, the agent-based Huff model outperforms the original Huff model in simulating family dining choices (Tables 5 and 6).

Table 6. Huff's Model calibration and validation (*p*-values of two-sample *t* test).

Distance Beta	Size		Healthfulness	
	Fast Food	Full-Service	Fast Food	Full-Service
Beta = 0	<0.01	<0.01	<0.01	<0.01
Beta = 0.5	<0.01	<0.01	<0.01	<0.01
Beta = 1	<0.01	<0.01	<0.01	<0.01
Beta = 1.5	<0.01	<0.01	<0.01	<0.01
Beta = 2	<0.01	<0.01	<0.01	<0.01
Beta = 2.5	<0.01	<0.01	<0.01	<0.01
Beta = 3	<0.01	<0.01	<0.01	<0.01
Beta = 3.5	<0.01	<0.01	<0.01	<0.01
Beta = 4	<0.01	<0.01	<0.01	<0.01

3.3. Family Restaurant Choices and Children's Weight Status

Using the optimal distance-decay parameters (β = 3; 2.5), we obtained simulated family restaurant choices with the agent-based Huff model using size and healthfulness as restaurant attractiveness indicators, respectively. Table 7 summarizes the correlation results between children's BMI percentile and simulated family restaurant choices. With restaurant size indicating attractiveness, children's BMI percentile was not correlated with the likelihood of dining at fast food restaurants. However, children's weight status was marginally significant with the frequency of patronizing high-quality fast food restaurants ($r = -0.077$, $p < 0.1$). This reveals that children tended to have normal weight if their family often chose to dine at healthier fast food restaurants (e.g., Subway). Counter to our expectations, children had a higher risk of being overweight or obese if their family often dined at full-service restaurants ($r = 0.072$, $p < 0.1$), particularly low-quality full-service restaurants ($r = 0.084$, $p < 0.05$). When using healthfulness scores to represent restaurant attractiveness, we found that children's weight status had no relation to family choices of either fast food or full-service restaurants.

Table 7. Correlation results of children's weight status and family restaurant choices simulated by the agent-based Huff Model.

		Fast Food	High Quality FF	Low Quality FF	Full Service	High Quality FS	Low Quality FS
A_j = size (β = 3)	Weight	−0.034	−0.077 *	−0.033	0.072 *	0.028	0.084 **
A_j = healthfulness (β = 2.5)	Weight	0.013	−0.004	−0.010	0.050	−0.023	0.034

Note: * significant at 10% significance level; ** significant at 5% significance level.

4. Discussion

Our findings generally align with recent studies showing that food environments cannot be evaluated only according to accessibility or number and type of food outlets [64,66–68]. Given this fact, we further evaluated out-of-home food environments with consideration also for food nutrition and healthfulness [69,70] and restaurant sizes [29]. However, the combined information on location, size, and nutrition still was not sufficient for prediction of the surveyed children's weight status (Figures 2 and 3). It is simply not possible to capture the complexity of food environments without examining both the dynamic competition between restaurants and the spatial interactions between food retailers and consumers of various social ranks [16,29,71]. This study has developed a hybrid agent-based Huff model in order to simulate probabilities that children and families choose specific restaurants. The validation results have demonstrated the reliability of this model for simulating family dining patterns (Table 5). This model was constructed under an analytical framework that integrates spatial interaction theory and socio-ecological models while also considering individual and community sociodemographic factors, restaurant location, size, and healthfulness, the spatial dynamics between consumers and food retailers, and competition among restaurants. This model also overcomes the limitations of traditional spatial interaction models, which estimate consumers' choices as a simple function of the friction and attraction of a destination to consumers (Table 6) [24,29,72,73].

This research is one of the first investigations of its kind to focus on rural African American children. Previous research has confirmed that both fast food and full-service restaurant dining are associated with higher energy intake and poorer diet quality [3,7,21]. However, prior studies have produced conflicting findings regarding children's dining choices and weight gain. Some found no association between children's weight gain and differential exposure to food outlets [74–78]. Others found that increased fast food access [79–81] or a higher ratio of fast food to full-service restaurants [81] was associated with a higher BMI. Unlike the extant literature, our results suggest that fast food in general has no impact on rural children's BMI percentile. Rather, our study even finds high-quality fast food to be conducive to children's good health (Table 7). It is worth mentioning that children had a higher risk of being overweight or obese if their family often dined at full-service restaurants, especially at low-quality ones. We believe that children's weight status might be influenced more significantly by family choice of food quality and healthfulness rather than by restaurant type. Unlike fast food restaurants' well-known reputation for providing energy-dense foods [13], the potential risks to children's weight status and health while eating at full-service restaurants might be less obvious to parents. With increases in women in the workforce and families with single parents, there will likely be additional time pressures on families that result in increases in the percentage of children eating outside of the home [82]. We assert that parents should increase their awareness of good food selection for their children in both fast food and full-service restaurants. There has been a recent call in the scientific literature to help parents and families to make healthier decisions when dining out [83]. Some positive menu changes have been implemented by restaurants [84,85], for example, improving the nutritional quality of food, providing healthier default options for children's meals, and adding easy-to-read nutritional information on menus for parents [85–87]. However, there is a gap between parents' positive intentions to feed their children healthy food and their actual food parenting behaviors [88,89]. For instance, in survey research parents reported wanting to feed their children in accordance with nutrition guidelines, but actually fed them more sweets and less nutritious foods [88,90]. Therefore, what foods are available in the food environment might be more important than parents' nutrition knowledge and intentions [88]. An industry-wide change in the food retailing industry is still in need to further enhance nutritional quality in restaurant settings, for example, providing dietary guidelines and easy-to-read labels/menus and enacting regulation of food marketing and policies affecting healthy food prices [86,87].

5. Conclusions

In conclusion, using both primary data collected from elementary schools and restaurants as well as secondary data, this research enriches the literature by thoroughly assessing a rural dining food environment, effectively simulating the restaurant choices of African American families, and examining the impact of choices on children's weight status in eastern Alabama. This study will hopefully increase public awareness of the importance of family restaurant choices and the risk that dining at low-quality restaurants poses for children's health. However, a few limitations should be noted. Neither family income nor parental education levels were collected through surveys due to parents' concerns over releasing these data. The addition of family level income and education data might improve simulation results. Second, age was not reflected in the model although this is an important factor related to dining choices. According to the National Health and Nutrition Examination Survey (2011–2012), children aged 2–11 consumed 8.7% of the total calories on average from fast food while adolescents aged 12–19 consumed 16.9% of the total calories on average from fast food. Another study found that 33% of children aged 2–11 and 41% of adolescents aged 12–19 consumed at fast food restaurants [3]. Among the 613 surveyed students in our study, only 5 were aged 12–13 while the other 608 children were aged 4–11. Due to the biased children and adolescent samples, we did not include age as a factor in the model. Third, street distances between children's homes and restaurants were used to represent the distance-decay effect in the model. Different transportation modes, also an important factor determining rural dinning patterns, were not taken into consideration. Fourth, given that consumer loyalty and revisit intention are closely related to the service quality of restaurants [5], future research considering more survey data and restaurant service quality information would provide new insight into the dining behaviors of rural children and families. In addition, we used Google Earth image to estimate the sizes of restaurants; however, the actual seat capacity may better reflect the attractiveness of restaurants.

Author Contributions: Y.L. designed the analytical framework of this study, provided methodological advice, supervised students to collect survey data, and wrote the paper. T.D. integrated primary and secondary data, conducted GIS and statistical analysis, and wrote and ran the code of the agent-based Huff model. J.P. provided suggestions on model construction and made revisions to the manuscript.

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