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Socioeconomic Inequalities in Children's Accessibility to Food Retailing: Examining the Roles of Mobility and Time

Abstract

Childhood overweight and obesity rates in Canada are at concerning levels, more apparently so for individuals of lower socioeconomic status (SES). Accessibility to food establishments likely influences patterns of food consumption, a contributor to body weight. Previous work has found that households living in lower income neighbourhoods tend to have greater geographical accessibility to unhealthy food establishments and lower accessibility to healthy food stores. This study contributes to the literature on neighbourhood inequalities in accessibility to healthy foods by explicitly focusing on children, an understudied population, and by incorporating mobility and time into metrics of accessibility. Accessibility to both healthy and unhealthy food retailing is measured within children's activity spaces using Road Network and Activity Location Buffering methods. Weekday vs. weekend accessibility to food establishments is then compared. The results suggest that children attending lower SES schools had almost two times the density of fast food establishments and marginally higher supermarket densities in their activity spaces. Children attending higher SES schools also had much larger activity spaces. All children had higher supermarket densities during weekdays than on weekend days.

Keywords: Canada, Food accessibility, socioeconomic status, activity space, mobility, children, health

1. Introduction

A large body of work investigates the relationship between neighbourhood environmental features and body weight, specifically by examining determinants of food consumption and physical activity behaviours. Accessibility to food retailing and services is an example of such a neighbourhood feature. Within the context of food environment studies supermarkets and grocery stores have often been assumed to offer accessibility to healthy foods because they offer a wide range of healthy food options at affordable prices, while fast food establishments and restaurants are typically viewed as sources of unhealthy, affordable, and high calorie food (Smoyer-Tomic, 2008). Many studies report a positive correlation between accessibility to fast food and poor health indicators such as weight status or high Body Mass Index (BMI) (Davis & Carpenter, 2009; Dubowitz et al., 2012; Jeffery, 2006), obesity (Maddock, 2004), unhealthy purchasing behaviour (He et al., 2012), mortality rates (Alter & Eny, 2005), and acute coronary syndrome hospital admissions (Alter & Eny, 2005). Other studies report a positive relationship between accessibility to supermarkets or grocery stores and positive health indicators such a healthy bodyweight (Dubowitz et al., 2012; Lamichhane et al., 2012; Morland, Diez-Roux & Wing, 2006) and increased fruit and vegetable consumption among low-income households (Rose and Richards, 2004). Critically, some studies report the opposite or only a partial relationship between accessibility to healthy or unhealthy food establishments and objectively measured or self-reported health status (Casey et al., 2008; Frank et al., 2009; Inagami, Cohen, Brown & Asch, 2009; Morland & Evenson, 2009; Rundle et al., 2009).

Research also shows a relationship between socioeconomic status (SES), measured by income, education, and/or occupation, and diet. Evidence of positive correlation between proportion of diets that correspond with current dietary recommendations and socioeconomic status is reported in the literature for adults (Dubois & Girard, 2001) and children (Dubois, 2006). Intersecting food accessibility with class, multiple studies also report greater availability of fast food outlets in low-income areas (Blair Lewis et al., 2008; Burns & Inglis, 2007, Cummins, McKay & Macintyre, 2005, MacDonald, Cummins and Macintyre, 2007; Pearce et al., 2007; Powell et al., 2007; Reidpath et al., 2002). Accessibility to supermarkets has also frequently been found to be poorer in low-income neighbourhoods in Canada and the U.S. (Apparicio, Micic & Shearmur, 2005; Lamichhane et al., 2013). Socially disadvantaged neighbourhoods with poor access to healthy food have been called 'food deserts' (Cummins & Macintyre, 2002). While most of this food environment research focuses on the household or adults as the behavioural units of analysis, less effort has been directed at studying food accessibility in childhood. Child-specific findings indicate that fast food restaurants have been found more frequently close to low-income schools in Canada (Kestens & Daniel, 2010) and in the US (Walker, Block and Kawachi, 2014; Zenk & Powell, 2008). Taken for granted in the food environment literature is the identity of children as autonomous food consumers with increasing power to purchase independent from adults (McNeal, 2002; Valkenburg and Cantor, 2001; Veiga Neto, 2013). The sections below describe in detail how this study contributes to food environment research, namely by embedding mobility and time into a child centred study of accessibility to food retailing and services.

1.1 Mobility

Much of the literature examining the relationship between food accessibility, socioeconomic status, and health has been conducted at the neighbourhood scale (Chaix, 2009). While important, many scholars have been critical of the conceptualization and measurement of "environment" and "neighbourhood" in the food access/desert literature (Chaix; 2009, Cummins; 2007, Diez Roux; 2004, Kwan; 2012, Oakes; 2003, and Widener & Shannon; 2014). Specifically, the residential neighbourhood is most commonly measured using a pre-defined administrative area such as a census tract, postal code area, or buffered area around a home address (Chaix, 2009). Everyday life, of course, is not limited to the residential neighbourhood as individuals are exposed to determinants of health both within and beyond their neighbourhoods. Focusing solely on the residential neighbourhood can therefore lead to misleading results; for example, one could live in a food desert but work nearby many sources of healthy and affordable food. The assumption that only the 'local' matters for health and its determinants has been termed the 'local trap' (Cummins, 2007). A promising method to overcome the 'local trap' may be to measure exposure to social and environmental determinants of health within an individual's activity space. Activity spaces are the "locations with which the individual has direct contact as the result of day-to-day activities" (Horton & Reynolds, 1971, p.37). In other words, activity spaces are a spatial representation of individuals' activity and mobility patterns.

Some recent work has considered accessibility to food stores using spatial units of analysis that incorporate mobility. Widener et al. (2013) used a time-geographic approach that generated an accessibility score that incorporated commuting patterns and activity constraints to measure accessibility to healthy foods among residents of Cincinnati, Ohio.

Salze et al. (2011) used a potential accessibility index as a method to estimate spatial accessibility to food outlets and sports facilities for regional car commuters in the Bas-Rhin *département* region in Eastern France. Incorporating commuting, as both of these studies have done, improves upon environmental representation. There are, however, many other instances of mobility and activity in everyday life. Horner and Wood (2014) accounted for a broader range of trips when they modelled individual-level food accessibility in Tallahassee, Florida using their eleven participants' activity patterns and time budgets. Using regional travel survey data, Kestens et al. (2012) assessed food exposure and health in Montréal and Québec city residents' activity spaces and found that models considering both residential and non-residential food exposure better predicted men's risk of overweight than those focusing solely on residential exposure. Zenk et al. (2011) investigated the determinants of physical activity and diet within activity spaces using a food diary and found that fast food outlet density within the activity space was positively associated with poor eating behaviour (i.e., positive association with saturated fat intake and negative association with whole grains). Crawford et al. (2014) compared women's supermarket and farmers' market exposure using a host of non-residential methods, including an activity space metric. They found that different methods result in different exposure results, demonstrating the importance of thinking critically about the scale used in food environment research. Using global positioning system (GPS) data, Shearer et al. (2014) found that adolescents visit food stores outside their residential neighbourhoods more than those within them.

1.2 Time

Traditional neighbourhood measurements are not only immobile; they are also

atemporal. Research into how food accessibility changes over time, due to the intersection between hours of operation of food establishments (availability in time), and household activity scheduling and patterns can potentially inform policy on the timing of food-related public health interventions. Unfortunately, most studies do not consider the time of day stores are open, when individuals have access to them, and seasonal changes in food retailers' operations and product mix (Chen & Clark, 2013; Widener, Metcalf & Bar-Yam, 2011). For example, individuals may work by a supermarket that is closed when their shift is over, mobile food vendors may sell unhealthy foods outside a high school over lunch periods, and farmers markets may only provide healthy and affordable options to retailers during the harvest season. Incorporating children's mobility patterns into measures of accessibility, as this study does, provides a unique opportunity to consider how accessibility varies with time because children's activity patterns are known to vary on weekdays and weekend days (Buliung et al., 2008; Rowlands, Pilgrim & Eston, 2008). There is no reason to think that the food environment is temporally static. In response, this study investigates how accessibility to food establishments varies over the course of the week (i.e., weekdays vs. weekend days).

1.3 Children

This study also addresses a gap in the literature by focusing on children, rather than adults. Children are a population experiencing concerning levels of weight gain (Active Healthy Kids Canada, 2013) and whose eating behaviours are likely influenced by their accessibility to food establishments. Children are also frequently autonomous consumers (Valkenburg and Cantor, 2001; Veiga Neto, 2013) whose buying capacity has grown sharply in recent years (McNeal, 2002). Children between the ages of 4 and 12

purchased 30 billion US dollars of goods in 2002, one third of which was spent on food items (McNeal, 2002). By the age of eight, children begin purchasing items independently; the majority of these early independent purchases are of sweet and salty snacks bought primarily at convenience stores (McNeal, 2002). Children's mobility patterns also differ from those of adults and adolescents. Therefore, findings from adult or adolescent-centric food accessibility studies that incorporate mobility and their resulting policies may not be applicable to children.

This paper assesses how the accessibility to supermarkets and fast food establishments varies for children attending schools of high and low SES as they move throughout the day and over the course of a week. This study provides original insight into how place, SES, and mobility could influence children's food accessibility and how food accessibility varies over the course of the week. Accessibility to the foodscape is conceptualized and measured using children's activity spaces as the geographic unit of analysis. Therefore, this paper uses an approach that considers children's mobility patterns and is not victim to the 'local trap' (Cummins, 2007). Given that children of lower socioeconomic standing are known to exhibit poorer health, this study aims to understand if such children have poorer accessibility to potentially health promoting food stores (supermarkets) and greater accessibility to potentially health harming food stores (fast food establishments) than children attending schools with qualities indicating higher SES.

2. Methods

2.1 Data & Sample

This study builds on and uses data from project BEAT (Built Environment Active Transportation): an ongoing, large scale, multidisciplinary and mixed methods study that analyzes the association between school transportation modes, activity levels of Toronto schoolchildren aged 10-11 years and the built environment (www.beat.utoronto.ca). Amongst other data collection activities, participants completed an activity-travel survey in spring 2010 and fall 2011. These diaries contained two components: a survey asking for household demographic characteristics and an activity-travel log. Four hundred and sixty-nine elementary schools in Toronto were originally invited to participate in the BEAT study (Buliung et al., 2013). Sixteen of schools were selected for this research and eight hundred and eighty-one parents gave consent to take part in the study (Buliung et al., 2013). Because the research emphasizes SES differences, multiple data sources at three different scales (neighbourhood, school, and household) were studied in order to select a socioeconomically diverse sub-sample from the Toronto-wide study. The sample selection process at each scale is described in detail below. The final sample is comprised of 104 children attending three schools: one high SES school located in a high SES neighbourhood whose students come from households demonstrating higher SES characteristics and two low SES schools located in lower SES neighbourhoods whose students live in households exhibiting lower SES attributes. While the study assigns children to two SES categories, high and low SES schools, three schools were included in the analysis in order to improve sample sizes for each category. The sample size of the high SES school (n=56) is similar to that of the two low SES schools combined (n=48) due to poorer survey return and completion rates in the lower SES schools (a total of 88 activity diaries from the two low SES schools and 65 at the high SES school were

returned). Lower income individuals and families are known to participate less frequently and have lower survey return rates than higher income individuals (Schnirer & Stack-Cutler, 2011). Both the Toronto District School Board and University of Toronto's Research Ethics Board approved this project. However, research ethics does not permit publication of neighbourhood or school identity, therefore to preserve confidentiality and anonymity, the three schools that partook in the study will be referred to as low SES school 1, low SES school 2, and high SES school. The neighbourhoods in which these schools are located will be referred to as low SES neighbourhood 1, low SES neighbourhood 2, and high SES neighbourhood. In the remainder of the paper children attending the two low SES schools are referred to as the low SES sample and children attending the high SES are referred to as the high SES sample.

2.1.1 Household

The survey component of the activity diaries was used in order to examine household level SES characteristics of the sample. Parents of children attending the higher SES school had higher levels of education, higher rates of full time employment, and higher rates of home ownership than those of children attending the lower SES schools (Table 1).

Table 1. Household SES Characteristics [a]

		High SES School		Low SES School 1		Low SES School 2	
		%	*n*	%	*n*	%	*n*
Father's Educational Attainment	Elementary school	0.00	0	10.00	2	14.29	4
	Secondary school	12.50	7	15.00	3	17.86	5
	College	17.86	10	0.00	0	17.86	5
	University	42.86	24	40.00	8	10.71	3
	Graduate school	23.21	13	5.00	1	3.57	1
	Not applicable	0.00	0	15.00	3	14.29	4

	Unknown	3.57	2	15.00	3	21.43	6
Mother's Educational Attainment	Elementary school	0.00	0	10.00	2	10.71	3
	Secondary school	5.36	3	20.00	4	32.14	9
	College	19.64	11	15.00	3	25.00	7
	University	46.43	26	30.00	6	10.71	3
	Graduate school	23.21	13	0.00	0	0.00	0
	Not applicable	1.79	1	10.00	2	7.14	2
	Unknown	3.57	2	15.00	3	14.29	4
Father's Employment Status	Employed full-time	82.14	46	60.00	12	25.00	7
	Employed part-time	5.36	3	0.00	0	7.14	2
	Student full-time	0.00	0	0.00	0	3.57	1
	Student part-time	0.00	0	0.00	0	3.57	1
	At home with children	1.79	1	10.00	2	10.71	3
	Without paid employment	1.79	1	0.00	0	3.57	1
	Not applicable	7.14	4	15.00	3	25.00	7
	Unknown	1.79	1	15.00	3	21.43	6
Mother's Employment Status	Employed full-time	48.21	27	40.00	8	32.14	9
	Employed part-time	23.21	13	10.00	2	10.71	3
	Student full-time	1.79	1	5.00	1	3.57	1
	Student part-time	0.00	0	20.00	4	0.00	0
	At home with children	16.07	9	10.00	2	32.14	9
	Without paid employment	0.00	0	0.00	0	0.00	0
	Not applicable	7.14	4	15.00	3	7.14	2
	Unknown	3.57	2	0.00	0	14.29	4
Home Ownership	Own (%, *n*)	85.71	48	20.00	4	10.71	3
	Rent (%, *n*)	12.50	7	70.00	14	82.14	23
	Unknown (%, *n*)	1.79	1	10.00	2	7.14	2

[a] Data from Project BEAT Activity Diaries

2.1.2 School

The Toronto District School Board uses a composite Learning Opportunities Index (LOI) to rank board schools in terms of relative need (TDSB, 2011). The LOI is composed of: median income, percentage of families whose income is below the low income measure (before tax), percentage of families receiving social assistance, adults without a high school diploma, adults with University degrees, and lone-parent families (TDSB, 2011). The school with the greatest external challenges is ranked 1 and as the challenges lessen the score decreases and the ranking increases (TDSB, 2011). Low SES

schools 1 and 2 have a much higher LOI score (0.8428 and 0.8173 respectively) than the high SES school (0.1223) (Table 2). The Fraser Institute compiles indicators of school performance (average levels of reading, writing, and math, gender gaps in levels of reading and math, % of tests below standard, and % of tests not written) into report cards so that the academic performance of individual schools can be compared (The Fraser Institute, 2014). In 2012, the Institute gave low SES schools 1 and 2 much lower ratings on academic performance (0.9/10 and 4/10 respectively) than the high SES school (8/10) (Table 2).

Table 2. Socioeconomic Characteristics of Schools

		High SES School	Low SES School 1	Low SES School 2
School's Socioeconomic Indicators	LOI 2011 Score [a]	0.1223	0.8428	0.8173
	LOI 2011 Rank [a]	424	64	86
	School's Rating (/10) 2012 [b]	8	4	0.9
	Mean Yearly Parental Income (CAD) [b]	126, 400	30,400	31,300

[a] Data from Toronto District School Board 2011 Learning Opportunities Index
[b] Data from the Fraser Institute (2014)

2.1.3 Neighbourhood

Neighbourhood level socioeconomic indicators were taken from Statistics Canada's 2006 Census (Statistics Canada, 2009). The indicators reported correspond to the census tracts in which the children's schools are located. The majority of children attending the low SES schools also lived within their schools' census tract (93.75%). Only 50% of the high SES sample lived within their school's census tract, however 85.7% of these children lived within 500 m of their schools' census tract. All socioeconomic indicators for the high SES neighbourhood, the census tract in which the high SES school is located, are

above the Toronto average (see Table 3). The two low SES census tracts have significantly lower scores on all socioeconomic indicators than the high SES neighbourhood (Table 3). These neighbourhoods also have, for the most part, lower than citywide average SES indicators (Table 3).

Table 3. Indicators of Socioeconomic Status for Three Toronto Neighbourhoods[(a)]

	Toronto Average	High SES Census tract	Low SES Census tract 1	Low SES Census tract 2
Median income 2005- all Census families (CAD)	69,321	96,409	36,548	45,970
Median after-tax income 2005- all census tract families (CAD)	59,879	80,132	34,476	41,268
Rented dwellings (%)	32.43%	55.40%	75.52%	86.02%
Population not in labor force (%)	31.70%	26.44%	38.19%	28.15%
Unemployment rate (%)	6.70%	5.30%	9.10%	7.90%
Less than high school education- population 15 years or older (%)	19.73%	10.34%	27.36%	15.64%
With a university degree - population 15 years or older (%)	26.71%	49.51%	24.12%	30.40%

[(a)] Data from Statistics Canada (2009)

Study schools were also purposively selected because they are in bordering neighbourhoods and were built during the same era (1872, 1874 and 1887) (TDSB, 2014a; TDSB, 2014b; TDSB, 2014c) and within neighbourhoods with similar built environments with regard to street design, public transport services, and design of commercial strips. One distinguishing built feature of the low SES neighbourhoods is the presence of many apartment towers, buildings known to house low-income residents (City of Toronto, 2011). As such, any differences in exposure to food services will not reflect drastic differences in land use in transport across study neighbourhoods, these are

highly walkable neighbourhoods, dating to the mid-to-late 19th century, and now served by similar types of public transit rolling stock; namely, streetcars and buses.

2.2 Activity Space Estimation

There are many ways to conceptualize, construct and estimate activity spaces and their various geometric and geographic properties. Using data from the activity-travel logs in the children's activity diaries, two methods were used in this study: the Road Network Buffer and the Activity Location Buffer. The activity-travel diary provided an activity-travel log in which caregivers and child respondents were asked to document the type, to/from travel mode, duration, and location of every activity in which a child participated over the course of four consecutive days (2 weekdays, and 2 weekend days). All activities documented in the diaries were considered in this study. If the first or last activity documented in a child's day did not take place in their own, a relative's, or a friend's home, an activity was added at their home address. Therefore, all children began and ended their day at home, unless they indicated otherwise. Therefore, daily activity spaces consist of activity chains beginning and ultimately ending at home (Table 4). Only children documenting at least three activities on all four survey days (2 week days and 2 weekend days) were selected into the study.

Table 4. Example of a Child's Activity Diary Entry

Day of the Week	Activity order	Activity Description	Activity Location	Duration	Travel Mode
Tuesday	Activity #1	Sleeping	Home	7h20	-
	Activity #2	Choir	School	0h50	Car, Van, or Truck
	Activity #3	School	School	3h00	-

Activity #4	Lunch	Home	1h00	Walk
Activity #5	School	School	3h45	Walk
Activity #6	Snack	Home	0h40m	Walk
Activity #7	Yoga	Yoga Studio	2h00	Car, van, or Truck
Activity #8	Dinner	Home	3h35	Car, Van, or Truck
Activity #9	Sleeping	Home	2h15	-

The first activity space measurement used is called the Road Network Buffer. This method is similar to that used by Sherman et al. (2005) and the Shortest Path Network used by Horner and Wood (2014). This type of activity space consists of the area around a shortest path children might take as they moved by foot, bicycle, public transit, or car from one activity to the next throughout the four days they participated in this study. Mapped routes between activities were not available, network shortest path estimation using the Network Analyst extension of ArcGIS 10.2 was used to generate activity routes between activities chronologically ordered according to the order of entry in the activity-travel diaries. A 500m, round-ended, buffer was then placed around these routes; a child can walk 500 metres in approximately 10 minutes (Timperio, 2003) (Figure 1).

A second method, which the authors term the Activity Location Buffer, was used that incorporated mobility without considering the transportation network. Instead, the area around each location the children indicated visiting was assessed (Figure 1). In order to calculate this activity space, a 500m buffer was placed around the location of each documented activity. Both methods consider mobility and non-residential food access. The first acknowledges that the transportation network shapes people's potential activity

locations while the second takes into account mobility as it considers residential and non-residential places children visited. Given that children's activity patterns are known to vary during week and weekend days (Rowlands, Pilgrim & Eston, 2008), three activity spaces were constructed for each child using both methods: all four days of observation, weekdays only, and weekend days.

<insert Figure 1 here>

Figure 1. Example of Children's Activity Space: the Road Network Buffer (left) and the Activity Location Buffer (right).
All home and school locations have been removed in these examples in order to preserve anonymity.

2.3 Foodstores

Toronto Public Health provided geocoded food outlet locations in the City of Toronto dating to 2011. This data is derived from Toronto Public Health's Toronto Healthy Environments Inspection System database. Supermarkets and fast food outlets were extracted from these data. Supermarkets were defined as food stores that sell large volumes of food, have multiple functions, and may include speciality departments such as delis, butcher shops, bakeries or seafood counters. All fast food chains, pizza, burger and/or fried chicken establishments (identified by name), and all hot dog carts in the city were considered fast food outlets. Coffee shops, cafes, cafeterias and sit-down non fast food chain restaurants were not considered fast food.

The food establishment data only existed for the City of Toronto. Many activity spaces, however, extend beyond the city limits. In order to account for this, only the area within the City of Toronto's limits was considered for activity spaces that surpassed the city's boundaries when calculating the density of fast food outlets and supermarkets (nb. establishments/ km^2 of activity space within the city limits). This density of fast food

establishments and supermarkets was compared across the groups of children to study SES based differences in food accessibility The Shapiro-Wilks test for normality was performed on all variables and those without normal distributions were log transformed (normalized) in order to perform difference of means t-tests on activity space dimensions and food metrics.

3. Results

Regardless of method or days of the week, the high SES sample partook in more activities than low SES sample ($p<0.05$) (Table 5). The weekly activity spaces of the high SES sample were almost two times the size of the low SES sample ($p<0.01$). This discrepancy in size was more pronounced during the weekend where the high SES sample had an average shape area of 39.60 km^2 and the low SES sample had one of 20.39 km^2 (Table 5). More children attending the high SES school left the City of Toronto during the study period (35.71% vs. 14.58%), particularly during the weekend (35.71% vs. 14.58% during the weekend and 5.36% vs. 2.08% during the week).

Table 5: Activity Space Dimensions

	Week			**Week days**			**Weekend days**		
	High SES (n=56)	Low SES (n=48)	*p-value*	High SES (n=56)	Low SES (n=48)	*p-value*	High SES (n=56)	Low SES (n=48)	*p-value*
Average number of activities	34.80	30.15	***	16.29	14.81	**	17.82	15.33	***
Road Network Buffer									
Average shape length (km)	82.17	46.36	***	13.96	15.24	***	77.52	39.70	***
Average shape area (km^2)	42.74	24.07	***	6.63	7.20	**	39.60	20.39	***
Activity Location Buffer									
Average shape length (km)	14.76	10.23	***	7.61	5.76	***	11.63	8.66	***
Average shape area (km^2)	4.11	2.77	***	2.14	1.61	***	3.09	2.27	***

*** = p-value < 0.01, ** = p-value < 0.05, *=p-value<0.1

Irrespective of method or day, children attending the low SES schools had greater densities of both fast food and grocery store establishments in their activity spaces ($p<0.01$) (Table 6). For both activity space calculations, this discrepancy between the high and low SES sample's exposure to the food establishments was more pronounced for fast food outlets: the low SES sample had somewhat more grocery stores available to them ($p<0.01$) and approximately two times the density of fast food establishments ($p<0.01$) in their activity spaces than the high SES sample (Table 6).

Table 6. Food Accessibility

	Week			**Week days**			**Weekend days**		
	High SES (n=56)	Low SES (n=48)	*p-value*	High SES (n=56)	Low SES (n=48)	*p-value*	High SES (n=56)	Low SES (n=48)	*p-value*
Road Network Buffer									
Supermarket Density (nb./km^2)	1.85	2.36	***	2.19	2.86	***	1.80	2.33	***
Fast Food density (nb./km^2)	6.33	12.65	***	5.31	10.98	***	5.51	11.62	***
Activity Location Buffer									
Supermarket Density (nb./km^2)	1.91	2.90	***	2.06	3.15	***	1.71	2.66	***
Fast Food density (nb./km^2)	8.48	16.59	***	5.61	12.17	***	7.52	15.15	***

*** = p-value < 0.01, ** = p-value < 0.05, *=p-value<0.1

The children's activity space dimensions and food accessibility changed over the course of the week. The high SES sample partook in slightly more activities during the weekend than during weekdays ($p<0.05$). There was no significant difference between the number of activities documented in the activity diaries on weekend and weekdays for the low

SES sample (Table 7). Regardless of activity space method or socioeconomic status, children had larger weekend than weekday activity spaces (average shape length and average shape area) ($p<0.01$) (Table 7). The children also had a higher density of grocery stores in their activity spaces during the week, irrespective of method or SES ($p<0.05$), than during the weekend. There was no statistically significant difference in availability of fast food restaurants by days of the week except for the high SES sample using the Activity Location Buffer. In this case, children attending the high SES school had a higher density of fast food establishments in their activity spaces during weekend days than weekdays ($p<0.05$) (Table 7).

Table 7. Weekday vs. Weekend Activity Space Analysis

	High SES		*p-value*	**Low SES**		*p-value*
	Weekday	Weekend		Weekday	Weekend	
Average number of activities	16.29	17.82	**	14.81	15.33	
Road Network Buffer						
Average shape length (km)	13.96	77.52	***	15.24	39.70	***
Average shape area (km2)	6.63	39.60	***	7.20	20.39	***
Supermarket density (nb./km^2)	2.19	1.80	***	2.86	2.33	***
Fast Food density (nb./km^2)	5.31	5.51		10.98	11.62	
Activity Location Buffer						
Average area (km2)	2.14	3.07	***	1.64	2.32	***
Supermarket density (nb./km^2)	2.06	1.71	**	3.15	2.66	***
Fast food density (nb./km^2)	5.61	7.52	**	12.17	15.15	

*** = p-value < 0.01, ** = p-value < 0.05, *=p-value<0.1

4. Discussion

This study makes three contributions to the food accessibility literature. Firstly, the relationship between SES and accessibility to healthy and unhealthy food establishments in a child-specific environment, an understudied population, is examined. Secondly, a method is used that incorporates children's activities and mobility rather than relying on static residential measures of accessibility. Finally, this research improves our understanding about how accessibility to food establishments varies over time, specifically over the course of the week.

Results demonstrate that the low SES sample had greater accessibility to fast food establishments, a source of unhealthy food, than the high SES sample. While socioeconomic discrepancies in the food accessibility have been found in previous work, this study's methodological and theoretical approach reveals that these discrepancies are not solely due to place of residence: children attending the low SES schools had greater objectively measured accessibility to fast food outlets than children attending high SES school as they moved throughout the day. This finding suggests there may be environmental determinants at play in this study area producing neighbourhood inequality with regard to objective accessibility to healthy food establishments. With these data in mind, key questions arise with regard to the institutional, political, economic and historical dimensions that contribute to the production of unhealthy food environments within lower income neighbourhoods.

Given that many studies (Apparicio et al., 2007; Morland & Diez Roux, 2006) have found poorer accessibility to supermarkets in low-income neighbourhoods, the grocery store analysis results for this study were unexpected: the low SES sample had higher availability of supermarkets than the high SES sample. This result could be due to

the activity space method used that incorporates children's mobility into accessibility measures. Perhaps supermarket accessibility does vary by neighbourhood, but individuals leave their neighbourhoods to seek out healthy food stores or leave their neighbourhoods for other purposes and are exposed to healthy food stores in the process. Using the Road Network Buffer method, the activity spaces were calculated using the shortest route between consecutive activities; therefore, the use of minor and major arterials may have been overrepresented in the potential paths. Since supermarkets tend to be built on these types of streets in order to be easily auto-accessible, the number of supermarkets in the children's activity spaces may be overestimated. This potential inaccuracy is likely to affect the children attending the low SES schools more as there were lower rates of car ownership (21% vs. 48%) as well as lower rates of car travel (25% vs. 55%) amongst this demographic. It is therefore possible that the supermarket density is smaller in practice than measured, especially in the low SES sample's activity spaces. Also, with respect to in-home consumption, it is generally parents, rather than children, who shop for food for their family's in-home consumption – especially for young children, as was the case in this study. These parents do not necessarily bring their children with them to the grocery store. Therefore, an analysis of parents' activity spaces may be more accurate when assessing children's' food accessibility for in-home consumption. This is not the case with fast food outlets where individuals, parents and children alike, generally eat on the premises of the establishment.

Similar to this analysis, two Canadian studies (Larsen & Gilliland, 2008; Bertrand et al., 2008) found no or a negative association between neighbourhood supermarket accessibility and income. These findings may imply that supermarket accessibility does

not vary by SES in the Canadian context. On the other hand, all children had supermarkets accessible in their weekly activity spaces; none of the children inhabited food deserts. It is possible that above a certain threshold density of supermarkets, individuals have adequate accessibility to places selling healthy foods for in home consumption. In this case, it may be that the correlation between supermarket density, health status, and SES was unexpected because all children under study have adequate accessibility to supermarkets. Poor health status in low SES neighbourhoods may be more prominent when there is a complete lack of options: when individuals live in food deserts.

This study examined food accessibility broadly; it considered food establishments available to children in their activity spaces and did not consider where individuals actually shopped, the quality of the supermarkets in question (e.g., the options present in the stores, the price, etc.), or individual behaviour when buying groceries. All food retail establishments are considered equal in this study, however, previous research has found that food quality and cost varies by type of food store and income-level of a neighbourhood. Cummins and Macintyre (2002) found in their study of Glasgow, Scotland, that the price of food varied by retail type and that unhealthy foods (poorer-quality & high-fat foods) were sold at lower prices in low-income areas. When Block and Kouba (2005) compared grocery stores in a high and a low income neighbourhood in Chicago, they found that grocery stores in the low-income neighbourhood generally carried produce at competitive prices, but of unacceptable quality.

Where one shops is only one part of the story; adults making food choices for their households could also be selecting unhealthy foods within a supermarket. Sooman

et al. (1993) and Barratt (1997) found that healthier options are, in general, more expensive than unhealthy options when purchased at the same food establishment or area. Therefore, it is also possible that the children's caretakers select unhealthy foods in stores that have healthy options because healthier options are, in general, more expensive. There is also the issue of the micro-geography of food product placement within a supermarket. Food retailers are known to locate unhealthy food products within particularly accessible and high traffic areas within stores, going so far as to place products containing recognizable child friendly advertising (e.g., cartoon characters) on shelves highly visible to children shopping with their parents (Dixon et al., 2006; Hebden et al., 2011). This product placement approach sets the stage for what is commonly referred to as 'pester power': for children to express their agency in household food decisions that may produce unhealthy outcomes as some parents choose to purchase an unhealthy food in an attempt to avoid or attenuate conflict (Campbell et al., 2012). Future research could test these hypotheses by administering a food diary along with an activity diary in order to examine how food environments affect actual grocery shopping and eating behaviours. Qualitative work could also compliment this research by considering the social factors that have been found to influence where people purchase food such as cultural food preferences, the racial/ethnic profile of shoppers and grocery stores, and financial resources (Hillier et al., 2011).

To the best of the authors' knowledge, this is the first study that considers how accessibility to food establishments varies with time. Results indicate that all children, regardless of SES and/or neighbourhood context, had a greater density of supermarkets in their weekday activity spaces. Previous research suggests that during the weekend, both

adults and children tend to consume less healthy diets than during weekdays. Haines et al. (2003) found that U.S. residents, children and adults alike, consume more total calories and calories from fat during weekend days than weekdays. In another study, Hart et al. (2011) investigated dietary patterns of obese children and found that they consumed fewer fruits and vegetables, more snack food and sweetened drinks, and a greater percentage of calories from fat on weekend days when compared to weekdays. Greater accessibility to healthy food establishments during weekdays may contribute to healthier eating habits during weekdays. The high SES sample also had greater accessibility to fast food establishments on weekend days, but this was only the case using the Activity Location Buffer method. Many children in the high SES sample left the city for the weekend (36% compared to 15% of the low SES sample). It is well known that roads leaving cities are typically surrounded with rest stops selling calorie dense foods served in fast food establishments (Dunn, 2010). Perhaps weekend accessibility to unhealthy food establishments within the highway system is a part of these children's weekend food environments that could contribute to the anticipated unhealthy eating behaviours children exhibit during the weekend.

An additional finding from this study is that children attending the high SES school have larger activity spaces than those attending the low SES schools. This means that these children travel further and are exposed to more of the city than their counterparts attending low SES schools. This discrepancy is likely due to weekend activity patterns. This was expected given that previous studies have found that low-income individuals have lower mobility rates (Pucher & Renne, 2003) and make fewer long-distance trips than higher income families (Mallett, 2001). Fewer travel episodes,

especially for long-distance trips, results in smaller activity spaces. Not surprisingly, the rate of car ownership was greater for families in the high SES sample (48% vs. 21%). Therefore, higher rates of car travel, a mode that suits long distance trips, most likely played a role in shaping the larger activity spaces among the high SES sample.

5. Limitations

For both activity space constructs, this study used a radial buffer of 500m. This distance was chosen in order to account for uncertainty in the children's route. Given that scale of analysis may influence results, future research can consider a broader range of buffer sizes. Furthermore, the lack of availability of data on the supermarkets and fast food outlets outside of the City of Toronto limited greater exploration of weekday-weekend differences in food accessibility. While the authors were interested in the planning and food policy implications within the City of Toronto, it would have been interesting to also incorporate exposure outside of the city limits. While a broader range of fast food establishments were considered in this study, specifically fast food establishments, hot dog carts and burger, pizza, and fried chicken establishments, future work could consider other sources of unhealthy foods such as convenience stores and gas stations, places that have transitioned from the core business of dispensing gas to providing access to processed and calorie-dense food and drinks. This study makes important contributions to the literature on child-specific food accessibility, however, it does not consider how children navigate their activity spaces, nor how their travel patterns differ from those of adults. Socioeconomic discrepancies were found in children's accessibility to unhealthy food. Future work could examine whether there is a causal relationship between accessibility to healthy and unhealthy food stores and

consumption/dietary behaviour. Furthermore, a child may use a supermarket differently than adults do; therefore, exposure to supermarkets may have different implications for adults and children. Future qualitative research is needed to investigate these hypotheses.

6. Conclusion

Many authors have called for research that considers non-residential exposure to food stores (e.g., Chaix, 2009; Cummins, 2007; Diez Roux, 2004; Kwan, 2012; Oakes, 2003, and Widener & Shannon, 2014) and how accessibility to food stores varies over time (Chen & Clark, 2013; Widener, Metcalf & Bar-Yam, 2011; Widerner & Shannon, 2014). This study provides an original contribution to the literature, by using an activity space approach that incorporates mobility into food accessibility metrics, by focusing on an under-studied population in this field, children, and by considering weekday and weekend day variations in food accessibility. Both methods used to measure the children's activity spaces are likely more accurate than commonly used measures such as residential neighbourhoods or household or school buffers as they incorporate children's mobility. This study demonstrates that activity space dimensions and food accessibility of children living in bordering neighbourhoods with similar built environments vary by socioeconomic status and weekday even when mobility patterns are considered.

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Socioeconomic Inequalities in Children's Accessibility to Food Retailing: Examining the Roles of Mobility and Time

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Figures

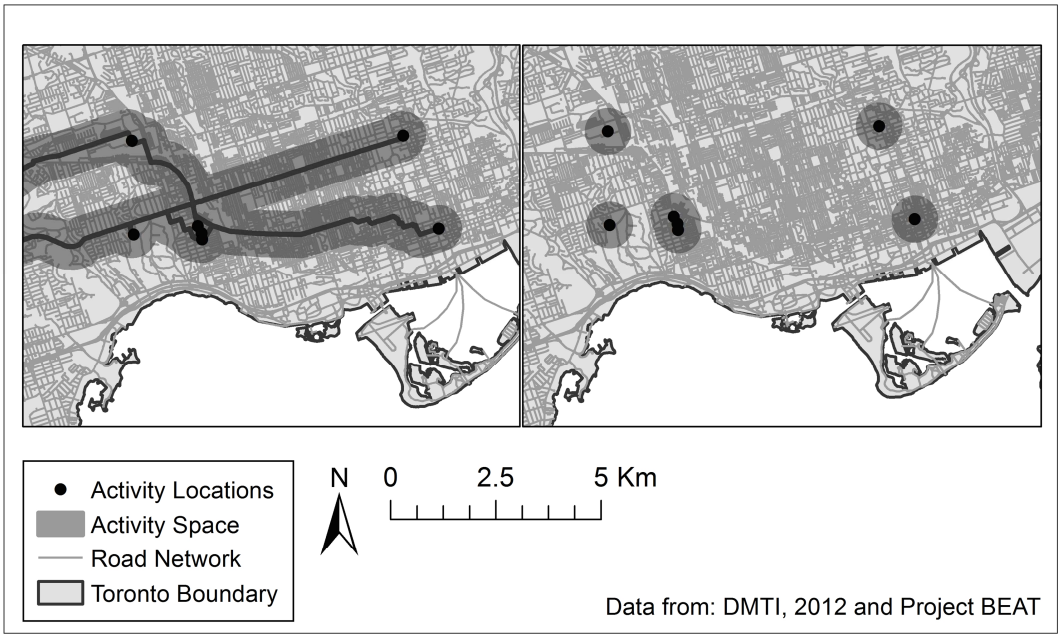

Figure 1. Example of Children's Activity Space: the Road Network Buffer (left) and the Activity Location Buffer (right).
All home and school locations have been removed in these examples in order to preserve anonymity.

Highlights

- This paper investigates SES discrepancies in children's food environments
- Contributions include the consideration of mobility and weekly variation in accessibility
- Fast food density is nearly twice as high for the low SES sample
- Supermarket density is marginally higher in the low SES sample's activity spaces
- Children have greater exposure to supermarkets during weekdays than weekend days