CHILDREN'S ACTIVITY AND TRANSPORTATION CHOICES: EXPLORING SOCIO-DEMOGRAPHIC CORRELATES AND HEALTH OUTCOMES

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Abstract

Children's activity and transportation choices: Exploring socio-demographic correlates and health outcomes

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Using data gathered from children aged 9-12 from Toronto (n=628), a cluster analysis was performed seeking to identify children's lifestyle activity and transportation choices, and associated physical activity accumulation. This research sought to identify whether activity and transportation choices could be combined in the same analysis and produce a composite profile. It also sought to determine if specific choice profiles could be associated with children's health outcomes as measured by Moderate to Vigorous Physical Activity (MVPA). A two-step cluster analysis was performed which identified five distinct clusters, namely Screeners, Artists, Athletes, Scholars and Mobiles. Athletes, with a high amount of sports participation had the best physical health outcome while Screeners, with little active activity engagement, had the worst. Socio-economic analyses were performed on all resultant clusters, identifying statistically significant patterns in household income, built form and gender.

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Dedication

For Amanda.

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1. Introduction

The rise in the rates of childhood obesity, which may be related to more sedentary lifestyles, makes the identification of contributing factors at young ages an urgent area of inquiry (Tudor-Locke et al., 2003, Stone et al., 2013). As a consequence, children's participation in various activities, use of transportation to access these activities, and resultant health outcomes have, over the last decade, become a significant topic of research (Gray et al., 2011; Caban et al., 2005; Faulkner et al., 2009; Buliung et al., 2009; Mendoza et al., 2011; Gorely et al., 2007; Seghers & Rutten, 2010).

Western countries have seen a change in children's activity participation behaviour in recent decades (James et al., 2001; Nader, 2008). Increased reliance on inactive forms of transportation and sedentary leisure activities has been on the rise at least since the mid-1980s (Buliung et al., 2009; Gray, 2014). With increased rates of childhood obesity, there is a need to identify activity patterns that could contribute to regular physical activity accumulation (Wang & Lobstein, 2006). Transportation usage habits and lifestyle activities have both been studied independently in relation to physical health outcomes. In the case of transportation, this has involved an exploration of active transportation modes (mainly walking and/or cycling) and independent mobility among children (Prezza et al., 2001; Fyhri & Hjorthol, 2009; Mitra, 2013; Mitra et al., 2014). Lifestyle choices studied in relation to health have included, among other things, diet, participation in sports, and categorical examinations of active versus sedentary activities, and unstructured play (Seghers & Rutten, 2010; Veitch et al., 2010; Omorou, 2015). Physical activity accumulation is commonly measured using metrics like the Body-Mass Index (BMI) or time spent engaged in Moderate to Vigorous Physical Activity (MVPA) (Mendoza et al., 2011; Tremblay et al, 2011). BMI provides a spectrum based on height and body weights to classify an individual as being healthy, underweight or overweight. MVPA describes the amount of higher energy activity an individual may undertake.

Studies examining lifestyle activity or transportation mode use independently have developed a number of methods and approaches that correlate choice with corresponding health outcomes. However, no study has yet been conducted which seeks to examine both lifestyle activity and transportation choice together in order to identify activity-transportation lifestyle patterns. In other words, a research gap exists at the intersection of both lifestyle activity and transportation choices in relation to health outcomes. Exploring these patterns may produce profiles of behavioural choice, which could lead to specific outcomes in children's health. By analyzing diverse activities simultaneously, a greater understanding of the interplay of these activities may be elucidated, along with their effects in terms of health.

The health outcome of an individual is a complex pattern of influencing factors. Physical activity engaged in by children originates from many sources including, but not limited to, transportation choice, leisure activity choice and school or work activities. Examining one of these three categories of work in relation to physical outcomes presents only part of the overall picture. A child who does not engage in active transportation, but participates in a large amount of organized sport activities may, in a study focused solely on transportation, skew results such that it appears as though transportation has little influence on health outcomes. The reverse may be true, where a child engaging in active transportation would also demonstrate a very active lifestyle, again skewing results for a study focused on only one of these two factors. In other words, patterns of activity and transportation behaviour may exist in children's daily life, and a systematic examination of daily activities and travel behaviour in tandem may produce more meaningful insights for policy.

For example, it might be possible to explain the health outcome based on both the amount and choice of transportation along with choices in lifestyle activities. Studies such as Seghers et al. (2010), which paired analysis of leisure activities with diet, demonstrate the importance of analyzing multiple independent activities with a composite outcome.

Within this context, this major research paper (MRP) contributes by improving our insights into the intersection between activity lifestyle and transportation choices and the resultant health outcomes of children. First, the paper seeks to identify patterns of daily activity behaviour and related travel among children. Second, the association between these activity-travel patterns and health outcomes in children will be explored. It must be emphasized that this paper seeks only to examine the physical outcomes of these activities as measured by MVPA, and that there are many additional health impacts which may accrue which are not addressed within the bounds of this research. Third, the paper explores if a child's activity participation and travel behaviour is related to their socio-demographic characteristics and residential locations. The method to be used for this study is cluster analysis, a classification method which has not yet been applied in this context, but has been used in similar studies (Bartko & Eccles, 2003; Patterson et al., 1994). Daily activity behaviour and travel by children living in the City of Toronto in Ontario, Canada, will be explored as a case study for this research.

This report begins with a short literature review of recent studies and progress made in research regarding the lifestyle activity and transportation choices in relation to children's health (Chapter 2). The development of these research disciplines is also briefly touched upon. Following this is the study design (Chapter 3), which discusses the study area, data sources and data analysis methods. The results of the analysis are presented afterwards (Chapter 4). These results are then discussed in relation to other similar, studies which were explored in the literature review (Chapter 5). A conclusion will then discuss future directions for this research (Chapter 6).

2. Literature Review

This section examines the history and recent advances in research related to the topic of this Master's Research Project. The research, which informs this project, is derived from a variety of different disciplines including, health, human geography and urban planning. This review has focused both on spatial analysis, different aspects of children's commute and, though it has focused mainly on the Toronto area, has also addressed broader geographic trends. The topics addressed may be generalized into three categories: studies into activity choices and health outcomes, studies into transportation choices and health outcomes and methodologies for analyzing multi-variate activity and behavioural patterns.

2.1: Activity choices and health outcomes

In 1998 the World Health Organization published the final text of the Expert Consultation on Obesity, one of the first major international examinations of increasing obesity rates (James et al., 2001). Patterns were beginning to emerge linking obesity not only to specific behavioural activities but also to factors such as socio-economic status (James et al., 2001). Initial studies into the causes of obesity tended to focus on adults and a range of variables including lifestyle choices such as smoking, amounts of physical activity engaged in and diet (Patterson et al., 1994; Johnson et al, 1998; Alberto et al., 2005; Reeves et al., 2005; Rovniak et al., 2010). More recent studies have begun to expand the focus of this research, targeting not only adults, but also adolescents and children (Nelson et al., 2005; Nelson et al., 2006; Gorely et al., 2007). The results of these studies indicate a disturbing trend, with international levels of childhood obesity almost universally on the rise (Wang & Lobstein, 2006).

This rise in childhood obesity prompted a burgeoning academic interest in the subject of children's physical activity outcomes. Within this field a scholarly discourse has developed exploring the relationship between specific activity choices and their associated outcomes in regards to health. The general structure of these studies involve determining a measurement of health outcome, usually either Body-Mass-Index (BMI), Moderate-to-Vigorous Physical Activity (MVPA) or a combination of these two and others (Mendoza et al., 2011). These aforementioned measures have been used in studies of individuals ranging from children to adults, and so may be applied to different age groups (Nelson et al., 2005; Nader et al., 2008; Omorou et al., 2015). This data may be collected using an activity diary

(Seghers & Rutten, 2010), a method of accelorometry (Cardon & Bourdeaudhuij, 2008; Omorou et al., 2015) or a combination of the two (Stone & Zeglen-Hunt, 2011).

Studies have found that North American children tend to engage in less than the recommended amount of MVPA on a daily basis (Stone & Zeglen-Hunt, 2011; Nader et al., 2008). The recommended threshold for an acceptable amount of MVPA is 60 minutes per day per week (Tremblay et al., 2011). Studies indicated that children tended to fall below this amount over time, though influencing factors have tended to vary (Faulkner et al., 2009; Stone et al., 2013).

2.2: Transportation choices and health outcomes

One of the activities which has been focused upon in recent years is the effect of transportation choice on children's health outcomes. This has been prompted by a shift in recent years to the use of personal vehicles for transportation to and from schools rather than the more traditional use of active transportation modes (Buliung et al., 2009). Active transportation modes, most specifically walking or bicycling, but also including any other means of movement with the human body as a source of power, are a source of significant MVPA (Faulkner et al., 2013; Cooper et al., 2003). A review conducted in 2009 indicated that the students using above-mean levels of active transportation also have higher physical-activity levels (Faulkner et al., 2009). Subsequent studies have suggested a stronger link between active commuting and improved outcomes in several health measures (Mendoza et al., 2011).

Identifying socio-ecological aspects that encourage the use of active transportation has attracted increased research interest. One such aspect are neighbourhood attributes. Variations in the neighbourhood built environment have been shown to have significant correlation with the use of active transportation (Buliung et al., 2009; Mitra & Buliung, 2012; Faulkner et al., 2013; Gray et al., 2014; Mitra & Buliung 2015; Curtis et al., 2015). Conclusions from these studies have supported distance as being a major influence insofar as transportation choice is considered (Faulkner et al., 2013, Curtis et al., 2015; Mitra & Buliung, 2015). Studies have also agreed that density of blocks, and urban built form supports a greater use of active transportation (Mitra & Buliung, 2012; Gray et al., 2014). As such this will be used as a variable to explore analysis results.

Socio-economic status must also be considered in conjunction with transportation. A recent review of literature on independent mobility and mode choice noted that many studies had indicated links between socio-economic status and transportation mode choice (Mitra, 2013). Higher economic status brings with it the greater possibility of car ownership, which would increase the chances of driven school commutes (Mitra, 2013). As to the propensity for low-income neighbourhoods to generate more active transportation trips, study results have been mixed (Mitra, 2013). A child's gender has also been explored by in an attempt to identify correlates, with mixed results again (Mitra, 2013). Gender and socio-economic status will also be used as exploratory variables.

A final avenue of transportation choice that has been examined is the household composition itself. This relates to the patterns of choice made by a child's primary care-giver (Mitra, 2013; Mitra et al., 2014). Parental choice is important in determining what sort of transportation a child uses to arrive at school (Mitra, 2013). The availability of a primary care giver to provide inactive transport may influence the choice of transportation for children (Mitra, 2013). In order to address this influence, an analysis of household composition will also be used to explore analysis results.

2.3: Studying lifestyle activity and transportation choices together

Transportation choices and lifestyle activities have mainly been studied separately. One of the more common methods of exploring these areas of study independently is through the use of cluster analysis (Nelson et al., 2006; Rovniak et al., 2010; Gorely et al., 2007; Omorou et al., 2015). These studies often also fail to consider transportation choices as a method of physical activity generation (Nelson et al., 2005; Nelson et al., 2006; Gorely et al., 2007).

There is precedence for studies which performed a composite analysis across more than one realm of inquiry. A notable example compared both lifestyle activity choices with diet and related it to a physical outcome (Seghers et al. 2010). In that study, four clusters were identified pairing lifestyle activity habits with food choices, which were then compared through a physical test in the form of a shuttle run (Seghers et al., 2010). The results indicated that both healthy and unhealthy habits existed within the different clusters (Seghers et al., 2010). If either diet or lifestyle activity had been independently analyzed, a completely different result may have been observed. By performing a combined analysis a 'profile' which describes multivariate choices with a predictable outcome may be generated.

3. Study Design

This chapter will discuss the design of the study which was used to perform the analysis which forms the backbone of this paper. It will address both the dataset upon which the study is based, as well as the manner in which that dataset was coded. Additional descriptive analyses undertaken on the clusters resulting from the analysis will be described, along with their significance to the study. Complications with the design will be addressed as well.

3.1: Study area

Toronto is the largest city in Canada with a metropolitan population of over 2.5 million people (Statistics Canada, 2011). The city features a diverse citizenry of different socio-economic statuses, household compositions and a plethora of activities and lifestyles (Statistics Canada, 2011). This makes the city suitably cosmopolitan for a study seeking to analyze multiple lifestyle and transportation choice but also address a spectrum of socio-economic statuses.

Toronto also has the unusual distinction of containing both very dense urban built form and less dense suburban form. This is due to the composition of the city itself. In 1998 the City of Toronto was formed from six former Municipalities: the Old City of Toronto, York, North York, East York, Etobicoke and Scarborough. Of these six municipalities, there is a significant differentiation in built form. The Old City of Toronto, historically the core around which most of the city developed, saw most of its inner core develop for the first time around the turn of the 20th century (Goad, 1913). Significant commercial development in the form of office towers typifies much of the central area, with the surrounding neighbourhoods an eclectic mix of styles. Streetcar suburbs mesh with 1960s style tower-in-the-park developments, along with single-family homes on small lots. The density is generally high in this area of the city, and typically urban with an approximately grid-based road system and strong access to public transportation in the form of busses, subways and streetcars.

The five other municipalities exhibit strong departures from this form. North York, York, East York, Etobicoke and Scarborough all saw significant development occur during the 1950s to the present, with a focus on typical suburban built form and density. Strip malls and large single-family homes abound. Lot sizes are large, curvilinear streets are much more common. Built form is generally low density, typical of most 20th century suburbs. There are pockets of density, but these are often isolated and built on the tower-in-the park model.

With the proliferation of suburban built form in the years following World War II there has been a corresponding dependence upon automobiles as a method of transportation in North America (Filion & Hammond, 2002). This trend has developed in tandem with an increase in public transportation options. Toronto is a city which has witnessed both changes in urban form, featuring both an expansive network of arterial roads and large freeways, as well as an extensive public transportation infrastructure including subways (Heavy Rail Transportation), street cars (trolleys) and a public bus system. This transportation system is representative of the transportation mix in most major North American cities. The City of Toronto also contains a dense inner-city and a more dispersed suburban outer belt. Suburban built form, having risen to prominence with dependence on the automobile, has been shown to correlate with reduced use of active transportation among children (Mitra & Buliung, 2012; Buliung et al. 2009; Faulkner et al., 2013). There have also been studies that indicated that there is no correlation (Ewing & Cervero, 2010; Mitra et al., 2010). The analysis of built form as it is associated with cluster profiles will serve to further the literature surrounding built form and its impact on active transportation use.

3.2: Data

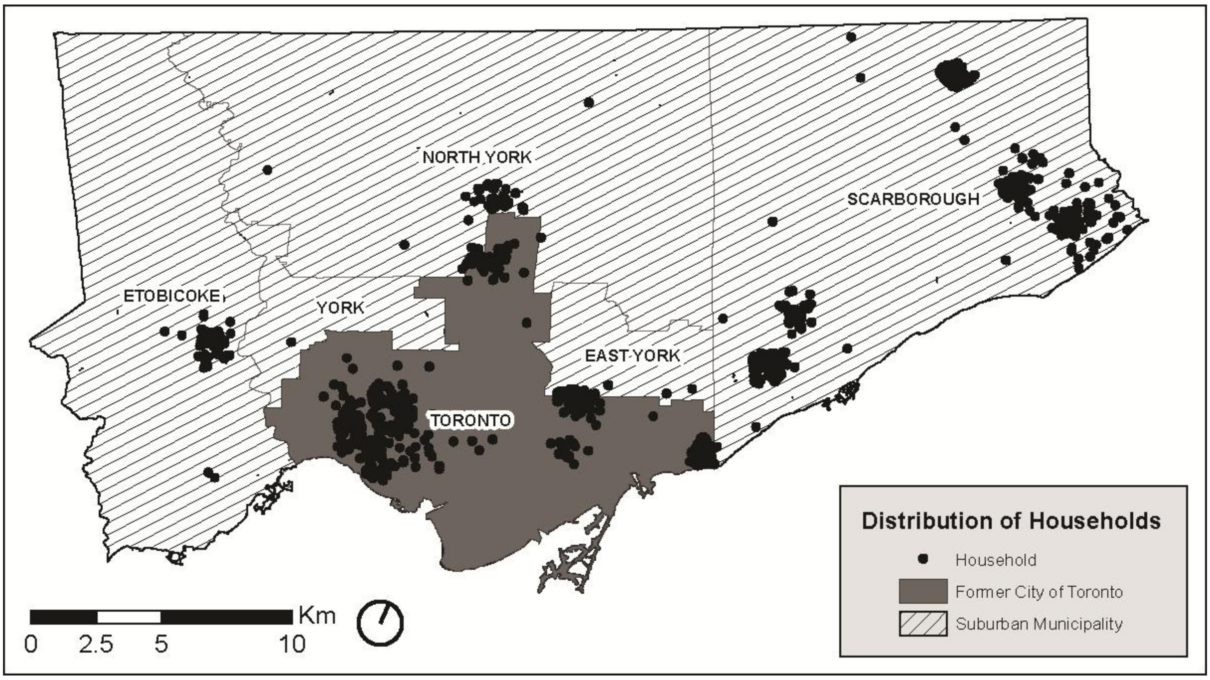
Data used in this study came from the project: Built Environment and Active Transportation (BEAT). Between April 2010 and June 2011, surveys were conducted among students in grade 5/6, who are enrolled 16 public elementary schools within the City of Toronto. Students' parents were also asked to complete surveys. The students were asked to wear an accelerometer while their parents, siblings or combinations thereof, recorded activities for the students in a travel diary/ journal (Guliani et al., 2015). The journal was to be filled with activities that took more than 15 minutes to perform. The type of activity and the duration would be identified. The mode of transportation used to go to that activity and leave it, if it occurred in a new location, was also recorded. Other information was collected through the survey, but it is not applicable to the design of this study. Data was to be collected over the course of four days: two weekdays and the weekend. Schools located in both inner-city and inner-suburban locations were included. A total of 1,027 students and their parents participated in the BEAT project.

In this paper, three types of data were analyzed: (1) survey data containing socio-demographic and geographical information about the children and their households, (2) data from the activity diary completed by parents for their children, and (3) objective data on physical activity participation collected using accelerometry. Due to the ongoing dialogue surrounding guidelines for what constitutes an appropriate BMI (James et al., 2001), this study utilized the less controversial MVPA, which has clearly established guidelines (Strong, 2005). The dataset, which resulted from the recording of the travel diary over the requested 4 days, included more than 27,000 individual activities by the 783 student participants.

Neighbourhood Built Environment

The advantage Toronto gives for this analysis is that in just one municipality a broad range of built forms are present. This variety may help partially explain a child's and their household's transportation and lifestyle choices. The access to transit and smaller distances between high-streets and shopping areas in the city may encourage active methods of transportation. Suburbs, with their wider roads, lack of sidewalks in many places, and longer distances to cover, may have the opposite effect. Studies have been conducted which support either result, and also contradict them (Faulkner et al., 2009; Panter et al., 2010; Ewing & Cervero, 2010; Mitra et al., 2010). Having these built forms both represented within a sample of students taken from the same school board is a unique opportunity to measure how this form may be represented within health outcomes. For the purposes of this study, the child's household location was codified as urban or suburban based upon the former municipal boundaries of Toronto. These boundaries and the location of households are depicted in Figure 3.1.

Figure 3.1 - Distribution of BEAT Participants in Toronto



Neighbourhood-level household Income

The BEAT survey itself did not contain a household income section. In order to gather information regarding household income, an approach that is similar to Mitra and Buliung (2012) was adopted. Their study measured the built environment correlates of active school transportation. The smallest geographic area for which income data is reported, the Dissemination Area (DA), was used to obtain median household income data from the 2006 census. A median of all DA level household incomes within a 250m buffer of the household was taken to represent the median income of the neighbourhood of residence for a student.

Using this method, the sample had a very close alignment to the actual median income of Toronto, with the median of the sample being $70,234 Canadian Dollars (CAD), only $494 above the population median of $69,740. This is a deviation of only 0.7% suggesting that the population is representative of the overall SES breakdown of the city (Statistics Canada, 2011).

Gender, Household Status and Age

All three of these socio-demographic datasets were recorded as part of the BEAT survey. Gender was self-reported. No additional data collection or processing was required in order to obtain this information.

Moderate to Vigorous Physical Activity (Outcomes)

The BEAT survey recorded the amount of MVPA of each child engaged in during the study through the use of an accelerometer. This data was then generalized to the number of minutes of MVPA engaged in by each child on a daily basis. The initial MVPA values ranged from a low of only 5.1 minutes of daily MVPA to a maximum of 86.3. The median value for the daily MVPA was 26.4 minutes, with the mean coming in slightly higher at 28.9 minutes, well below the recommended guideline of 60 minutes daily.

3.3: Identification of activity clusters

The primary focus in this research is combining activity and travel choices with an emphasis on physical health outcomes. Though both activity and travel choices have been analyzed independently, no study has yet sought to perform a combined, multi-variate analysis. One of the leading methods used to engage in these multivariate-analyses is the cluster analysis. Cluster analysis has been used in the past to study transportation choices, activity choices and health outcomes (Nelson et al., 2006; Rovniak et al., 2010; Seghers et al., 2010; Omorou et al. 2015). Cluster analysis focuses mainly on the process of categorization (Lattin et al., 2013). Given a large, apparently heterogeneous dataset, cluster analysis seeks to emphasize homogeneity among attribute distributions with a view to identifying groups of similar cases (Lattin et al., 2013). By grouping these homogenous clusters together a profile can be identified which may not be apparent otherwise. The resultant clusters may then have additional descriptive analyses explored. This study seeks to adapt this method of analysis by taking two very different elements of individual choice, lifestyle activity and transportation choices, and determining if there are similarities between the two of them. This has not yet been studied, and the results may present researchers with a new way of determining profiles of associated activities in children.

The greatest concern in performing a cluster analyses is that clusters will always be found, regardless of whether there is enough homogeneity to support them. However, there are well established methods for post-analysis verification, which provides a sufficient degree of confidence in the result (Lattin et al., 2013). Studies employing cluster analysis require some scrutiny in the selecting the variables which are chosen for study. Given its extensive use in similar studies in both topic and structure, cluster analysis was chosen as the core analytic method of this MRP.

3.3.1: Data preparation

A total of 783 students had provided travel diaries as part of the BEAT study. In order to conduct a cluster analysis, this data had to be refined and coded. The first refinement was to ensure that the sample used for analysis had recorded activities for both weekdays and weekend days. The reason for this filter was twofold. The first concern was that part of the study design was explicit in that the travel diary should record both weekdays and weekends. The second, and more important concern, is that the large amount of time which is not taken up by school during the weekend would skew the activities of children who only recorded for one type of day. Those that recorded only weekdays might demonstrate a comparatively low amount of lifestyle or leisure activities while recording weekend-days only would show an excess of these same activities. This could form a source of potential error by making outlying observations appear to be representative of the overall sample (Page et al., 2009; Stone et al., 2014).

Travel diaries which had recorded activities on two days or less were also removed from the sample. This resulted in any travel diary only containing information recorded from less than three days, and/or travel diaries recording information for only either weekdays or weekends, being excluded from the sample for the purposes of this study. This approach also assured that every child recorded at least one day where they should have attended school.

An additional filter was applied to the sample which sought to identify children which had recorded insufficient instances of travel for analysis. Due to this study's emphasis on exploring activity and transportation choices together in a single analytical framework, it was imperative that the final sample includes individuals with recorded travel. A threshold of three trips was chosen. This ensures that any travel diary must at least provide data on a trip outside of one day commuting (to/from school). This prevents children's engagement in different travel activities from representing only one day's travel patterns, a potential source of bias.

Upon completion of this filtering process, 59 students were removed from the sample (7.5%), resulting in a final sample size of n = 724 for further statistical analysis.

The students included in the final sample had recorded approximately 25,000 individual activities. The BEAT dataset had an associated duration divided by hours and minutes for each activity. The duration of each event would become the "distance" measure (i.e., the unit of analysis) used for clustering analysis. This is the core around which the cluster analysis is performed.

The activities reported in the travel diary were self-reported and open-ended (i.e., students wrote down whatever activities they had performed). This meant that there was no specific vocabulary or standardized means of notation for the different activities undertaken. In order to perform an analysis seeking to categorize the sample according to similar attributes, these varied activity descriptions required simplification and organization. In order to facilitate this, an overall list of 26 categories was created based on an initial review of all recorded activities and travel. These categories are listed in Table 3.1 along with a general description of which activities comprised each category.

Table 3.1 - Activity Categories and Descriptions

Category	Frequency	Description
Active Transportation	1175 *	Any form of transportation which employs human locomotion as the source of energy. This includes mainly bicycling and walking, but also skateboarding and other, similar activities.
After School Programs	55	Any day-care or similar program where children spend time following a school day
Appointment	47	Any appointment, such as a Doctor's or Dentist's
Arts	436	Activities such as painting, drama or colouring
Education	275	This category is comprised of activities where students received tutoring, or attended club activities which emphasize scholastic achievement
Homework	983	Activities described as 'Homework', 'Doing Homework', etc.
Leisure	131	Any time little movement is described in the activity without an associated, more clear description. Includes 'Resting', 'Relaxing' and 'hanging out' or similar. Days where students stayed home from school due to sickness are included here.
Meal	4478	Activities listed as meal times or similar.
Menial	1335	These are all activities such as 'cleaning room', 'changing clothes', or any other chore-like activity.
Inactive Transportation	845 *	This is any form of sedentary transportation, like being driven in a car or riding a form of public transportation
Active Unstructured Play	214	This is active, structured play, in which a child is playing a game like tag, or similar. The child must be actively moving but not free to do as they wish, but does not include sports.
Active Structured Play	1578	Active, unstructured play. These are instances where the child is moving actively but without any specific organizing structure. Playing in a playground would fit into this category, whereas playing tag would not. Entries including 'Play' or 'Playing' are included here. This decision is addressed in depth in the discussion.
Inactive	66	Sedentary, structured playing. An example is

Structured Play		playing a card game, or a board game.
Inactive Unstructured Play	23	Sedentary, unstructured playing, such as playing with building blocks.
Public Event	139	Any activity such as watching a concert or watching a sibling's sports game.
Reading	536	This category is only comprised of situations where the activity is specifically listed as 'reading'
Religious	200	This is any activity related to religious activity, such as attending church, or prayer time, and also studying religious texts
School	1317	This is only for activities recorded as 'school' or 'at school'.
Screentime	2911	This category broadly contains use of television, computer use and videogame play.
Shopping	554	This includes any instance of going to a store for groceries or any other shopping.
Sleeping	4540	Any entry such as 'sleeping' or 'napping'
Socializing	319	This category is comprised of entries like 'visiting family' or 'visiting friends'
Sports	1136	Any activity which is identifiably related to a sport or specifically identifies a sport e.g. 'hockey', 'skiing'. It does not include physical activities that can also be used as transportation, such as 'biking'.
Unclear	33	This category was used to isolate records which combined multiple activities. For example, 'television/studying/eating'.**
Work	27	Any activity listed as 'work' or 'working'.

* Some of these trips were missed in the initial survey. These are accounted for in later data processing which is described in this section.

** In cases where multiple activities were recorded, but one of them was not likely to supersede the other, then the first recorded activity was attributed the entirety of the recorded time. As an example, 'reading/napping' would be attributed to 'reading' due to the binary nature of the activities.

Once the categories had been developed, the next step was to assign activities accordingly. This required little discretion on behalf of the researcher for the majority of the activities that had been recorded. A more onerous problem arose while populating the categories corresponding to active and inactive transportation. In the design of the BEAT survey, the respondents reported the mode of transportation to reach different activities. However, the actual duration of the trip was not recorded. Diligent participants would often record trips if they were longer than 15 minutes. A total of 168 trips were removed due to having no associated travel mode. This format change was necessary, for without this information, it would be impossible to determine whether these trips were undertaken using active or inactive means of transportation.

This missing data posed a problem for the dataset but thanks to the robust nature of the BEAT data set, it was possible to design an alternative. Every activity was geo-located. The BEAT travel diary requested that if an activity took place in a different location than the prior activity the mode of this trip should be recorded, along with other information. Instances where this prior activity was recorded as something other than a trip indicated that a trip had gone unrecorded. Because of the geo-located nature of each activity, it would be possible through Geographic Information Systems (GIS) analysis to determine to a close approximation the distance of these journeys. In order to generate this information, each activity which recorded a mode of transport for which the prior activity was not a trip was identified. This activity and its prior activity were then paired together by X,Y values and the mode of arrival to the destination activity. This created a dataset with two geo-located points and an associated mode for unrecorded trip.

ArcGIS 10.3 was used to generate a straight-line between these two points. This straight line was then associated with its corresponding transportation mode, thus generating the base data needed to complete the rest of the unknown trips. With a straight line associated with a specific mode, the duration of each trip could be calculated. The expected speeds of each mode is listed in Table 3.2.

Table 3.2 - Transportation Mode and Estimated Speed

Mode of Transportation	Speed
Car, Van, or Truck	42 km/hr
Streetcar	14 km/hr
Bus	13 km/hr
Walking	4 km/hr
Biking	15 km/hr

(Neff & Dickens, 2013; HDR Corporation, 2008; Thompson et al., 1997)

As a result of the GIS processing, 4056 unrecorded trips were identified and added to the dataset. However, approximately 25% of these were trips under 5 minutes in duration. Any trips under 5 minutes in length were removed from the set, accounting for 1606 activities. The grand majority of these were errors in geo-location generating trips of less than 1 minute in length. 10 trips were also removed due to errors in geo-location that resulted in trips lasting hundreds of hours.

The purpose of this study was to identify daily patterns of activity and travel behaviour. As a result, categories that are not typical day-to-day activities were removed from further analysis. The reason for this is the arbitrary nature of the time and place which these activities may originate in. A dentist's appointment, for example, is not a daily or even weekly event for the majority of children. Activities which were mandated, like attendance to school, did not constitute choices, and were excluded. Categories were also removed which summarized a period of time in which a number of different activities may have taken place without any specificity. This would include activities recorded as something similar to 'after school program'. Activities which fulfilled a fundamental biological imperative were also removed as they would show little differentiation from child to child.

These categories were considered for the cluster analysis:

- Active Transportation
- Arts
- Education
- Inactive Transportation
- Active Structured Play
- Active Unstructured Play
- Inactive Structured Play
- Inactive Unstructured Play
- Reading
- Screentime
- Sports

Time spent by each child in each of these 11 categories was then used to generate a pivot-table. In this table, each child had a value for every activity, which represented the standardized number of minutes spent in that category over a typical week. This data was then analyzed in order to remove any significant outliers, those which had recorded too many or too little activities. In order to facilitate this, the standard deviation was taken of the entire sample. To normalize the dataset, any child with a reported number of minutes above 3 times the positive standard deviation, or any child below the 3 times negative standard deviation, was removed from further analysis. This resulted in 3 children being excluded from the study. 2 were also removed due to their having 0 minutes of recorded activities across all the relevant categories.

One final step taken prior to data analysis was the removal of any child which did not have an associated record for Moderate to Vigorous Physical Activity (MVPA) per day as obtained from the accelerometry readings. In order for us to explore the correlations between cluster membership and MVPA, only children with reported values for MVPA were included. Prior to this final step, 719 students remained in the sample. 91 children were removed (12.7%), taking the final analysis sample to n = 628. This number represents 61.1% of the initial sample population of 1027 and 80.2% of the 783 children which had recorded activity journals.

3.3.2: Cluster analysis

The cluster analysis was then performed using the Two-Step cluster model in SPSS. There are two main types of cluster analysis: Hierarchical and *k*-Means. In both methods, the analysis will always find clusters (Lattin et al., 2003). Hierarchical methods operate by starting the whole dataset as one group and dividing it into groups based on similar characteristics until every observation is separate (agglomerative). Hierarchical models may also operate in the opposite direction beginning with every observation separate and then grouping them by similar characteristics until only one group exists (divisive)(Lattin et al., 2003).

The *k*-Means analysis begins with an assumed number of groups and sorts observations into these groups by greatest possible similarity (partitioning) (Lattin et al., 2003). Both the strength and weakness of this method is the defined number of clusters. In situations where the number of clusters necessary for analysis is known in advance, then *k*-Means is the superior of the two methods. In analyses where the number of clusters is unknown, as in this study, the pre-selection of cluster numbers prior to analysis is arbitrary. The accepted methodology to address datasets where the number of final clusters is unknown is to combine the two methods (Lattin et al., 2003). In a two-step approach, a hierarchical analysis (divisive or agglomerative) is first performed to determine where and if there is a point where clearly separated clusters are generated. That provides the number of clusters which can then inform the *k*-Means cluster analysis. A *k*-Means cluster analysis is conducted with the desired number of clusters indicated. The hierarchical cluster analysis discerns how many clusters exist, while the *k*-Means cluster analysis uses the number of known clusters to more precisely assign observations to each one.

Cluster modelling will always discover clusters, regardless of any existing relation. This is a major potential source of error in the analysis method. However, there are ways to ensure that the cluster solution discovered is representative. For example, a pair of random samples taken from within the sample used for the analysis can be compared against each other through the same methodology used for the sample as a whole (Lattin et al., 2003). If the centroids of the clusters generated from these random samples conform closely to the centroids of the entire sample, the number of clusters can be assumed to representative of the sample. This allows a researcher to verify that the analysis of the entire sample is representative, and that the analysis has not found false clusters. SPSS's Two-Step method combines Hierarchical and *k*-Means clustering, as well as useful analytical and visualization tools. It was therefore selected as the method for this analysis.

The final step before proceeding was an analysis of variable validity. One of the shortcomings of cluster analysis is that it is greatly affected by outliers. For that reason the above step was taken to remove children with extremely high or low reported hours. Variables which are present in too few data points may also skew the results. Variables representing inactive unstructured play, inactive structured play and active structured play were all removed due to their swamping effect on initial cluster analysis outcomes. These variables likely contained too few observations to adequately represent the sample as a whole.

Once cluster analysis was completed, additional analyses were performed on the clusters in order to further understand the composition of each group.

3.4: Post-clustering descriptive statistics

Once the clusters had been established it was possible to investigate the characteristics of the children composing each individual cluster. Two methods of analysis for this were used, *chi*-Square tests and one-way analysis of variance tests (ANOVA), dependent upon the data being compared.

Chi-Square tests can be used for determining the significance of observed data distribution. The data used for this must be categorical in nature, for example, the gender of individuals (Lattin et al., 2003). For the purposes of this study, *chi*-Square tests were used in conjunction with descriptive variables with clusters generated through the Two-Step Cluster process as factors. This would aid in developing a descriptive profile which examined characteristics beyond lifestyle activity and transportation choices.

The one-way analysis of variance (ANOVA) test is a method which generalizes the *t*-test to more than two groups of analysis (Lattin et al., 2003). A statistical test which accommodates multiple groups is necessary considering that the results of a cluster analysis may result in more than two clusters. The ANOVA examines the mean of a variable across a number of groups to determine whether there is a statistical significance to any variation in group-by-group means. This determines whether a variable shows a statistically significant variance across clusters.

Following the cluster analysis, five additional analyses were conducted, each of these using the five identified clusters as the basis of the test. The purpose was twofold: to explore correlations between cluster membership and socio-economic status as well as residential location, and to explore the association between cluster membership and physical activity levels as measured by MVPA. The five additional variables investigated were the residential location of the child's neighbourhood, the age of the child, the gender of the child, the parental status of the child, and the social-economic status of the child's household.

MVPA as measured in minutes, being a continuous variable, is best analyzed in comparison to other variables using an analysis of variance (ANOVA) calculation . Once this test was conducted, the mean MVPA of each cluster was compared against the standards set forth by Tremblay et al. (2011) in their paper establishing Canadian Physical Activity guideline of 60 min. per day for children aged 5-11. The position of each cluster's mean

MVPA above or below this amount of daily MVPA was used establish the resultant health outcome. Comparisons were also made between clusters.

4. Results

This chapter presents the results of the cluster analysis and the additional analyses performed on the resultant clusters. It begins with a summary of the data from the initial dataset of activity and transportation categories included in the analysis. It then explores the variables used to further explore the cluster composition following the analysis. The cluster analysis results are then described, including whether it indicates that clusters are present. Following this the results of the ANOVA and *Chi*-Square tests will be presented and described. This chapter will terminate with the results of the health outcomes test as described by daily minutes of MVPA.

4.1: Summary Statistics of Time Spent in Activities and Travel

The following tables describe the filtered, refined dataset used for the cluster analysis. Table 4.1 shows the mean and standard deviation of engagement in minutes per week each activity or transportation choice, as well as MVPA in minutes, neighbourhood level median household income and age. As expected, some activities and transportation choices had significantly higher engagement than others. For example, extra-curricular education activities were much less frequently engaged in than screentime activities. This is due mainly to the nature of the activities themselves, with an activity like attending tutoring sessions being more difficult and less common an activity than watching television or playing videogames throughout the week. Categories with the two highest levels of engagement were screentime and active unstructured play. Both transportation choices had similar levels of engagement.

In terms of socio-economic status, the average household income was $69,227.08 (+/- $24,953.00); the average age of the sample was 10.52 (+/- 0.7) years; 47.5% of the sample lived in urban neighbourhoods; 55.8% of the children were female and 11.0% of the households were single-parent. On average, students accumulated 29.2 (+/-13.5) minutes of MVPA per day.

Table 4.1 - Engagement of Sample in Transportation and Activity Choice and Descriptive Statistics (n = 628)

	Mean	**Standard Deviation**	**Percentage**
Activity or Transportation Type			
Active Transportation (minutes/week)	104.58	128.25	-
Inactive Transportation (minutes/week)	83.29	105.82	-
Arts (minutes/week)	40.92	88.52	-
Education (minutes/week)	37.99	93.69	-
Active Unstructured Play (minutes/week)	214.41	236.69	-
Reading (minutes/week)	46.75	96.32	-
Screentime (minutes/week)	355.13	302.43	-
Sports (minutes/week)	132.40	195.04	-
Descriptive Statistics	0.00	0.00	-
MVPA (minutes)	29.02	13.50	-
Neighbourhood level median household incom (CAD)	69227.08	24953.00	-
Age (years)	10.52	0.70	-
Gender			
Male	-	-	44.2%
Female	-	-	55.8%
Residential Location (Built environment)			
Urban	-	-	47.3%
Suburban	-	-	52.7%
Household Structure			
Single Parent	-	-	11.0%
Not Single Parent	-	-	89.0%

4.2: Cluster analysis model

The clustering solution for the final set of variables had a silhouette rating of 'Fair' according to SPSS's description, which is indicated in Figure 4.1. Each data point in the cluster analysis is given a value from -1 to 1 representing its cohesion and separation. Cohesion and separation are measures of how closely the point conforms to the other points in its cluster membership compared to the other clusters (Lattin et al., 2003). Low values indicate that the data point is less distinct from other clusters, while high values mean that the data point is more similar to other points in its assigned cluster. The above graph shows the mean of all of the silhouette values for the dataset. This analysis resulted in a positive silhouette value, indicating that clusters are reasonably cohesive and distinct.

As for the identified clusters, Table 4.2 discusses the characteristics of each cluster and the percentage of the sample which it constitutes, while Table 4.3 indicates the mean engagement per activity or transportation choice by cluster.

Figure 4.1 - Cluster Analysis Model

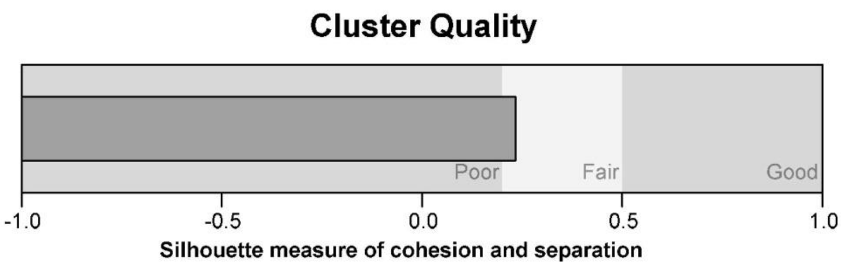


Table 4.2 - Cluster Characteristics and Size

Cluster Name	Cluster Characteristics	%
Screeners	Highest engagement in screentime, low or lowest engagement across all other categories, including active and inactive transportation	39.3%
Artists	Highest engagement in arts activities and inactive transportation, closer to mean engagement across all other categories	13.1%
Athletes	Highest engagement in sports, lowest engagement in reading, screentime, low in education	15.0%
Scholars	Highest engagement in education and reading, high engagement in active transportation, low in inactive transportation	13.1%
Mobiles	Highest engagement in active transportation, active unstructured play. Low participation in education and inactive transportation	19.6%

Table 4.2 provides names for all five clusters, a brief description of their characteristics, and the percentage of the sample which it composes.

Table 4.3 - Mean Activity or Transportation Participation (Minutes/Week)

Variable	Screeners	Artists	Athletes	Scholars	Mobiles
Active Transportation	49.7	96.7	79.4	103.9	239.7
Arts	22.9	154.4	25.6	36.9	15.8
Education	12.7	18.2	12.3	202.2	12.1
Inactive Transportation	48.7	202.1	131.7	57.7	53.7
Active Unstructured Play	123.5	266.1	146.4	173.7	441.7
Reading	34.5	39.3	31.0	155.3	16.0
Screentime	437.7	279.0	272.8	311.4	332.0
Sports	44.9	88.3	490.0	79.5	99.4

Table 4.3 indicates the mean of engagement in each activity or transportation choice per variable of each cluster. Note that although some clusters are particularly low, none are zero.

Five clusters were identified as a result of the analysis namely Screeners, Artists, Athletes, Scholars and Mobiles.

The first cluster comprised 247 of the 628 (39.3%) students in the sample, and had a low amount of engagement in extracurricular education, a low amount of reading, the most screen time and the lowest engagement levels in sports. This group also had the lowest mean minutes spent in active transportation, but somewhat surprisingly, also a very low amount of inactive transportation. This cluster surpassed its closest competitor for screentime by mean engagement time of 82 minutes per week. For future reference, this group will be referred to as the **'Screeners'**

The second cluster, with 82 of 628 (13.1%) individuals, had the highest amount of time spent engaged in arts. It also had the highest amount of inactive transportation use. This cluster fell in the mid-range for all other factors, not low or high in any particular activity. They were identified as being slightly more engaged in educational pursuits than all other clusters with the exception of one, though still below the mean of the sample. They also had a high incidence of active, unstructured play, the mean value being at least 96 minutes higher than three of the five other clusters. They occupied the middle position of the five clusters for active transportation use. Their inactive transportation use outpaced the nearest cluster by more than 90 minutes measured from mean. For ease of discussion, this group will be referred to as the '**Artists**' for the remainder of the study.

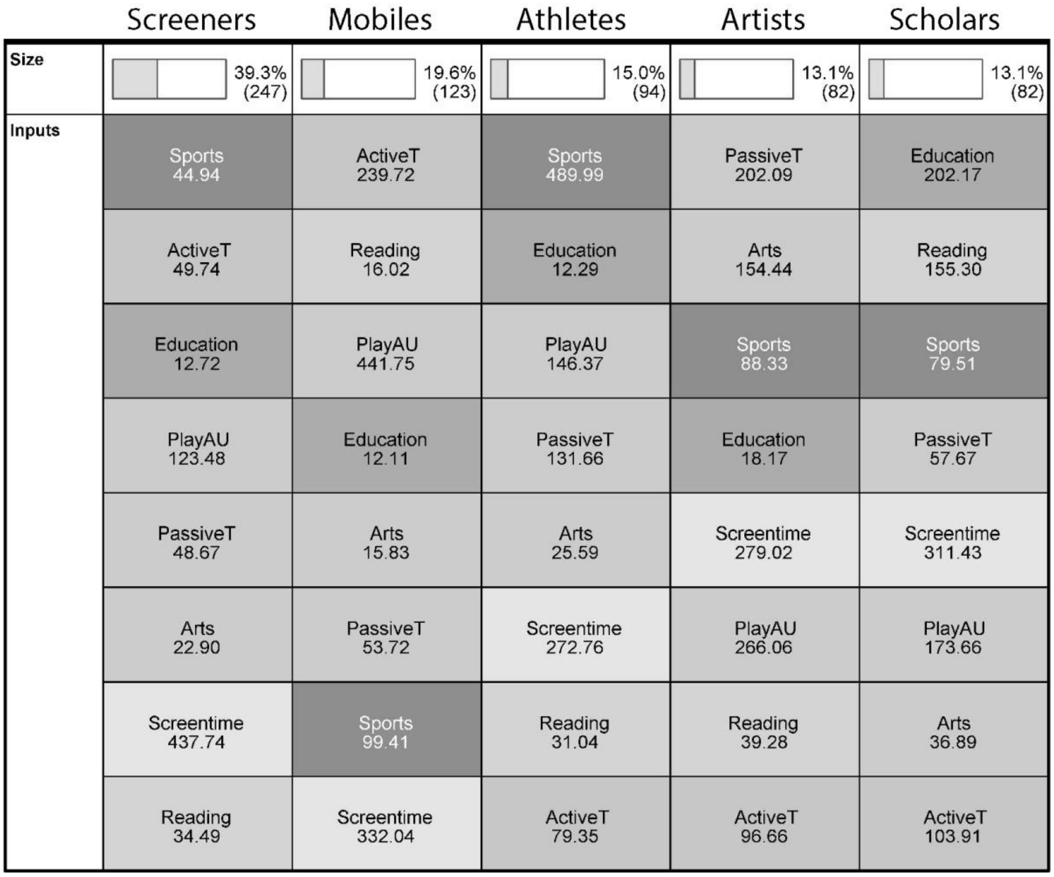
The third cluster, comprised of 94 of the 628 (15%) individuals in the sample, had one of the lowest amounts of extra-curricular education activities, the least amount of screen time and by far the highest amount of sports playing. This group was the second lowest value for mean active transportation use and was the mean for inactive transportation use. For ease of discussion, this group will be referred to as the '**Athletes**'.

Cluster number four, which was composed of 82 of the 628 (13.1%) individuals in the sample, had the highest mean extra-curricular education score with a mean 165 minutes higher than the means of the other four groups. This group also partook in the highest amount of reading, and will therefore be referred to as the '**Scholars**' for the remainder of this paper. This cluster had the lowest amount of inactive transportation use and the second highest use of active transportation.

The fifth and final cluster, 123 of 628 (19.6%) students, had both low extra-curricular art and education scores, along with a low mean in reading. They had a very high incidence of active, unstructured play, with the mean almost 200 minutes higher than the nearest cluster, the Artists. Their use of active transportation was also the highest, with a mean more than three times greater than the nearest cluster, the Scholars. Their use of inactive transportation was second from the lowest. They will be referred to as the '**Mobiles**' going forward.

The breakdown of activity category in determining cluster membership depicted in Figure 4.2 further describes the reasoning for each cluster's composition. The Screeners are mainly defined by their low engagement in sports and active transportation, while screentime had a very low importance despite it being the defining characteristic of this group. The Artists cluster was mainly defined by its use of inactive transportation and engagement arts activities, the two categories for which it had the highest participation rates. For the Athletes cluster, high participation in sports and low participation in education were the two main influencing variables. Active unstructured play also featured highest equally important for this group is it did for the Mobiles cluster, although this indicates a preference for low engagement. The Athletes cluster had the second lowest active unstructured play at 68 minutes below the mean. The Scholars cluster saw reading and extra-curricular education as the main variables determining cluster membership, for which it had the highest means. The Mobiles cluster saw its main variables for selection be use of active transportation and low scores in reading, making the high observed mean for active, unstructured play less important in cluster formation.

Figure 4.2 - Minutes of Activity Engagement by Cluster and Variable Strength in Cluster Formation



**The following variable names were truncated during analysis: Active Transportation (ActiveT), Inactive Transportation (PassiveT) and Active Unstructured Play (PlayAU).

Figure 4.2 indicates the breakdown of each cluster by the variables which had the greatest effect on its composition, in order of greatest to least. The saturation of each box indicates the importance of that variable in the global cluster analysis.   The size of the cluster is also indicated at the top of the graph, with the percentage of total sample and number of children in that cluster. Each variable also indicates the mean for that cluster in weekly engagement in minutes for that activity or transportation choice.

4.3: Cluster Analysis Variable Importance

Of the eight variables used in the final clustering solution, the variable controlling for engagement levels in sports and education had the strongest effect on cluster membership, which is indicated in Figure 4.3. Given the existence of two variables which had the potential to have a swamping influence on the cluster solution, arts and extra-curricular education, this indicates that their low mean engagement values did not skew results. It is also important that there is no greatly unequal relationship between the two overarching elements to the cluster analysis, activity and transportation choices. The order of influence which the variables had in determining clusters sees the two transportation categories as the third and fifth strongest influencers in cluster formation. Both of these variables fit on either side of the mean in this analysis. This indicates that neither of the two transportation modes were strongly favoured in the cluster solution, which suggests that a binary relationship does not exist when comparing them against lifestyle activities. A possible binary relationship would have been indicated by one or both of these variables as the strongest determining variable of cluster membership. Since this is not present in the findings, it suggests that the transportation variables, despite being binary in nature, did not create undue influence on the results.

As far as the fit of the model is concerned, it is acceptable but could be better. This is a large data set with several variables analyzed. As such, a 'Fair' cluster silhouette is not unexpected, but the proximity to a 'Poor' cluster silhouette as found in this study is less than ideal. In future studies, any clustering should hope to more clearly present a positive or negative silhouette of cohesion and separation. This concern aside, there is still sufficient evidence from qualitative sources that the clusters found are consistent with expected results. This research indicates that lifestyle activity choices can be analyzed in concert with transportation choices without one overwhelming the other.

Figure 4.3 - Variable Importance in Global Cluster Formation

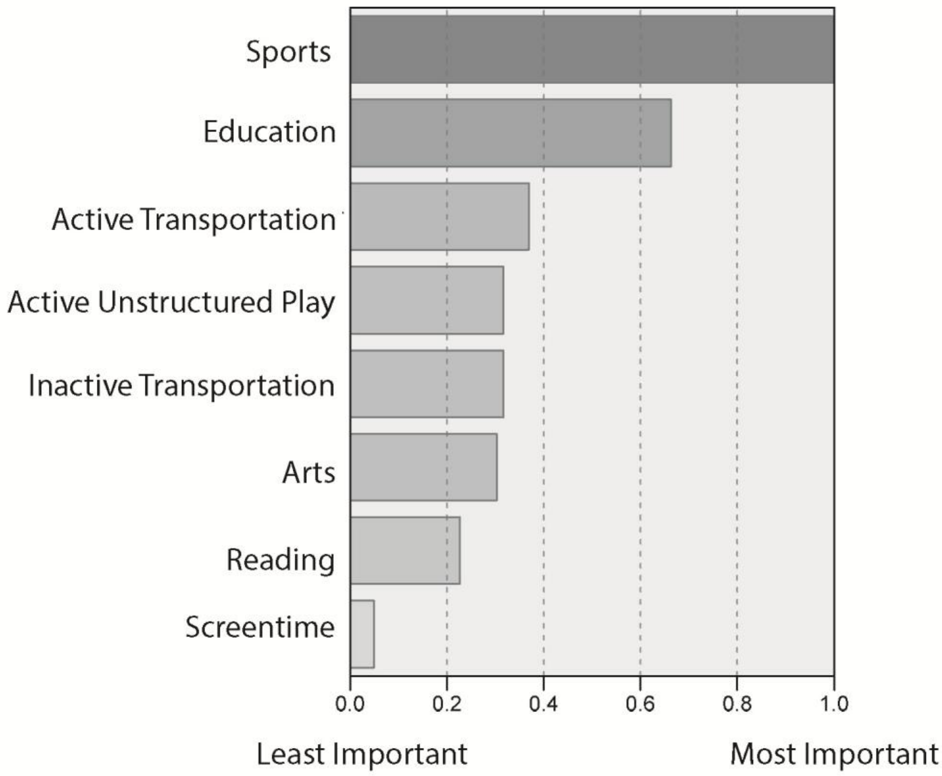


Figure 4.3 indicates how important each variable was in determining clusters across the dataset. The gradual decline from most important (Sports) to least (Screentime) indicates that there is no swamping variable which was responsible for determining the majority of the clusters. Many of them are close to evenly matched in importance.

4.4: Correlates of activity-travel clusters

Following the cluster analysis additional analyses examining descriptive characteristics were undertaken. The results of these tests are listed in Table 4.4. The Athletes cluster possessed the highest mean MVPA, with a total engagement of 35.44 minutes. The Mobiles cluster was the second highest with a mean of 32.21 daily minutes of MVPA. The Screeners had the lowest mean MVPA with a mean of only 25.50 minutes per day. Based on these results the Athletes have the best physical health outcomes while the Screeners have the worst physical health outcomes.

The income measurement indicated that the cluster with the highest mean income was the Athletes group at $75,073 87. The opposite end of the spectrum was occupied by the

Scholars group with a mean income of $61,186.34. The Screeners group was closest to the Toronto mean with an income of $67,661.71.

The analysis of the location of children's homes indicated that the Athletes cluster was the most urban (62.00%) while the Screeners cluster was the most suburban (63.20%). The Mobiles cluster had an exact 50% to 50% distribution indicating that members of this cluster were just as likely to originate from a suburban or urban location.

The age of the sample was found to deviate no greater than 0.11 from the 10.5 year mean for the sample.

Gender saw significant variation cluster-to-cluster with the Athletes cluster having the highest proportion of male membership (67.40%). The Artists cluster had the highest female membership (65.40%). The Mobiles cluster was 50.80% male membership and 49.2% female membership, making it almost equally likely for a child to be either gender in it. The Artists and Scholars group had lower male membership with 34.60% and 37.8% respectively.

Table 4.4 - Descriptive Statistics Analysis Results by Cluster

	Screeners	**Artists**	**Athletes**	**Scholars**	**Mobiles**
MVPA					
Mean	25.50	29.62	35.44	26.82	32.21
Std.	0.48	0.50	0.49	0.50	0.50
Household Income (CAD)					
Mean	67661.71	72292.14	75073.87	61186.34	71364.47
Std.	23301.00	27519.52	28057.39	19733.71	25731.63
Built Form					
Urban	36.80%	53.80%	62.00%	51.20%	50.00%
Suburban	63.20%	46.20%	38.00%	48.80%	50.00%
Age					
Mean	10.54	10.45	10.53	10.39	10.59
Std.	0.67	0.73	0.75	0.64	0.75
Gender					
Male	37.20%	34.60%	67.40%	37.80%	50.80%
Female	62.80%	65.40%	32.60%	62.20%	49.20%
Household Status					
Single Parent	10.90%	15.40%	4.30%	13.40%	11.70%
Not Single Parent	89.10%	84.60%	95.70%	86.60%	88.30%

Table 4.4 presents the descriptive statistics of each additional variable explored

As part of these additional exploratory analyses, tests showing statistical significance strength of association tests were performed. This study used a Confidence Interval of 95% to determine statistical significance, the results of which can be found in Table 4.5. These tests found that Income, MVPA, built form and gender were all statistically significant across the clusters, while household status and age were not. In addition, the strength of association for gender was identified as moderate (Cramer's phi = 0.226), while the built form association was weak (Cramer's phi = 0.184).

Table 4.5 - Correlates of Activity-travel Clusters

	Test Type	p-Value	Cramer's V	Statistically Significant at 95% CI
MVPA	ANOVA	0.000	n/a	Yes
Household Income	ANOVA	0.002	n/a	Yes
Built Form	Chi-Square	0.000	0.184	Yes
Age	ANOVA	0.275	n/a	No
Gender	Chi-Square	0.000	0.226	Yes
Household Status	Chi-Square	0.181	0.181	No

Table 4.5 indicates the significance of each statistical test performed on the clusters resulting from the cluster analysis. Four of the six tests indicated statistical significance.

5. Discussion

This chapter will discuss the results of the cluster analysis, health outcomes as well as the additional supporting analyses performed. Research results will then be discussed in regards to recent scholarly discourse. Areas of difficulty in the study will also be addressed, as will recommendations for researchers seeking to replicate this study in the future.

This study sought to contribute to the literature on children's transportation and activity choices. The results of this study have indicated that there are specific activity patterns which possibly lead to physical health outcomes. It has done so by, rather than examining isolated activities, combining both transportation and lifestyle choices into one analysis. The combined analysis of transportation and lifestyle activity choices in regards to health outcomes has not yet been performed, constituting a new contribution to the literature on this topic.

5.1: Health Outcomes

The results of this analysis show correlates which may have been anticipated. The Athletes and Mobiles both showed the highest amount of mean daily MVPA, with 33.35 minutes and 29.4 minutes of daily MVPA respectively. Both of these clusters had high participation in lifestyle activities or transportation choices which would contribute to overall MVPA counts, mainly active transportation, active unstructured play, and sports. The other three clusters had results below the mean, with the Screeners group the lowest at 25.5 minutes of MVPA per day. Of note is that not one of these clusters partook in an amount of daily MVPA which met or exceeded the Canadian Health Guidelines of 60 minutes. All five groups were well below this standard. Despite analyzing transportation in conjunction with activity choices, this result shows little differentiation among clusters from the overall population (Nader et al., 2008; Cardon & Bourdeaudhuij, 2008). It may be assumed that a cluster demonstrating the highest levels of physically intensive activities, such as sports, would see a result which placed it above the recommended 60 minute per day threshold. The analysis has indicated that the contrary is true, that regardless of high engagement in physical activities, the majority of the sample still fell below this threshold. The BEAT dataset itself indicated that 66% of participants do not achieve daily recommended MVPA levels on any day of the week (Stone & Zeglen-Hunt, 2011). This indicates that, even with increased participation in activities which lead to higher physical health outcomes, children in Toronto will not, on average, meet the recommended amount of MVPA.

When comparing across the five different clusters which were generated by the analysis, we have two very strong correlations which indicate better health outcomes in the form of greater MVPA. The Athletes and Mobiles groups both scored above the median MVPA and both shared several similar characteristics. This is consistent with the categories of activity that most typify these two groups as well. The Athletes group had the highest mean time in the sports category, while the Mobiles cluster had the highest mean in both active transportation, active unstructured play, and the second highest participation in sports. It is to be expected that groups exhibiting a high mean amount of time spent in any of these three categories would have a corresponding high amount of MVPA per day.

The other side of the MVPA grouping is occupied by the Scholars and Screeners groups. These groups both featured the lowest MVPA, with Screeners having the lowest and Scholars the second lowest. Both of these groups had low sports participation, with a mean of 44.9 and 79.5 minutes respectively. The Screeners group also had the lowest amount of active unstructured play and active transportation, consistent with its lowest mean MVPA. The Scholars, despite having the second highest active transportation use out of the sample, were also the second lowest in terms of time spent engaged in active, unstructured play. When comparing this against the categories in which these groups were strong, the position of these two on the opposite end of the MVPA spectrum becomes clear. Scholars had the highest mean amount of time spent reading and in extra-curricular education, while the Screeners had by far the highest mean screen time.

In terms of transportation use and physical health outcomes, a few noteworthy observations may be made. The possible correlations between active transportation and physical activity outcomes has already been addressed in other studies (Mendoza, 2011; Cardon & Bourdeaudhuij, 2008). The Athletes cluster, representing the best physical outcome, was third highest in active transportation use and second highest in inactive transportation use. The Scholars had the lowest use of inactive transportation but the second highest use of active transportation, which suggests that transportation choice did little to increase their overall MVPA, contradicting some research on the subject (Faulkner et al., 2009). The Screeners cluster was second lowest for passive transportation and lowest for active transportation which, combined with their lowest mean score for sports (mean of 44.9 minutes per week) and lowest active unstructured play, is consistent with this group having the lowest overall mean MVPA. This group does not travel much, nor does it engage in diverse activities. Compare this to the Artists group, with a middling result in most scores, and it is difficult to ascribe a specific result to the use of inactive transportation. It may simply be that there is a neutral effect of passive transportation on health outcomes, whereas active transportation has a more positive effect. That the Screeners cluster is the largest of the five clusters suggests that a large proportion of children do not engage in activities which result in a greater accumulation of MVPA.

The low amount of active transportation engaged in by the Screeners cluster and the lower observed MVPA accumulation is in line with current literature (Faulkner et al., 2009). In general, the bulk of studies have noticed that increased active transportation use results in higher MVPA accumulated (Faulkner et al., 2009). This study is consistent with these other studies.

In the end, we can identify several patterns which seem to indicate better health outcomes across lifestyle, transportation and also more general demographic and built form results.

5.2: Neighbourhood Household Income

The Socio-Economic Status (SES) of children is a major concern for any sort of study trying to identify trends in behaviour. A low or high SES may have significant effect upon the activities available to children (Mitra & Buliung, 2012). This is represented within the data set by, for example, children performing some sort of work as an activity. This may represent children having to work in family businesses or in other ways provide additional household income. In Ontario, the lowest legal working age is 14, and thus none of these children, aged 9 to 12, should have been engaged in any sort of work. The possibility that this was shorthand for other activities within the household does exit, but the very presence of this as a common enough activity to warrant a category is representative of differences in SES.

Of the five clusters, the Athletes cluster was found to have the highest mean household income. At $75,073.87, this is higher than the sample's mean by more than $5,800. The opposing end of this scale was the Scholars cluster, with a median income of only $61,186.34, more than $8000 lower than the mean of the sample. The Mobiles and Artists clusters were both above the mean of the sample by about $2,000 and $3,000 respectively, while the Screeners cluster was below the mean at $67,661.71. The Scholars cluster, with its high use of active transportation, and low household income, reflects studies which have shown a correlation between low-income neighbourhoods and active transportation use (Mitra & Buliung, 2012).

5.3: Built Form

When explored on the basis of built form, the Screener cluster showed 63.2% of the students in this group residing in the suburbs, while only 36.8%% resided in the more urban Old Toronto. This is an interesting statistic, given this group's lowest physical health outcome, and indicates the need for further analysis.

The Artists group was found to have 53.8% of its membership residing in the inner city and 46.2% residing in the suburbs. The preference towards the inner city is interesting given that this group had the highest mean inactive transportation use among all clusters. This would seem counter-intuitive given the presumed extensive use of automobiles common to the suburbs. This may simply indicate a large amount of public transportation use, although no data was available to support this hypothesis.

The Athletes cluster showed 62% of its membership inhabiting in the urban core of Toronto, with 38% occupying the more suburban reaches of the city. This indicated a strong inclination for the urban centre of the city, which is interesting given that active transportation use is not greatly increased. Urban form, with its denser block layout and shorter travel distances, is considered to encourage active transportation. This has not been reflected in the Athletes cluster membership.

The Scholars group presented a close to even distribution, with 51.2% urban and 48.8% suburban. This suggests that there is little to no correlation for this group in relation to built form. This conclusion is the same for the Mobiles group, which had an equal distribution of membership between the inner city and the suburbs.

In general, these results suggest that children living in urbanized areas take slightly more trips and tend to engage in more structured activity than those living in more suburban environments. The Scholars group, had a high participation in active transportation, and tended to be urban in character. This correlates with work indicating a positive association of active transportation with more compact block structures (Faulkner et al., 2013; Mitra & Buliung, 2015). The Screeners group, with its low participation in active transportation and high group concentration in the suburbs, reflects research which has indicated dispersed built form results in lower use of active transportation (Mitra & Buliung, 2012; Mitra & Buliung, 2015, Faulkner et al., 2009; D'Haese et al., 2015).

5.4: Age

The ages of the children in the study ranged from 9 to 12. The analysis indicated that there was no correlation between age and cluster membership. This is unsurprising given that the dataset addressed a very limited range of ages.

5.5: Gender

It must be noted that 55.8% of the respondents in this analysis are female (Table 4.2); this distribution of males vs. females in the sample is not representative of the Canadian population, which is 50.4% female and 49.6% male (Statistics Canada, 2011). The breakdown for the sample should be considered when examining descriptive statistics of the clusters. The results of the *chi*-Square test indicated that there was statistical significance to the distribution of genders to clusters, with a moderate level of association (Cramer's phi = 0.226)

The Screeners cluster showed 62.8% of its membership as being female and 37.2% of its cluster being male. This is a significant difference, indicating a strong preference towards female membership.

The Athletes cluster showed a striking, but not surprising, tilt towards males, with 32.6% of the group female and 67.4% male. Studies have indicated that gender difference in sports participation is not uncommon, and thus the 23% difference is not wholly unexpected (Eccles & Harold, 1991; Slater & Tiggemann, 2011). This result indicates that, between the two sexes, males are more likely to engage in sports and sports-like activities.

Within the Scholars cluster, there was a higher number of females at 62.2% of the constituents, with the remaining 37.8% being male. This denotes a preference towards female participation in this cluster.

The Mobiles group was found to have a composition of 49.2% female and 50.8% Male. Given the distribution of the sample between the two genders this group denotes a slight bias towards male membership.

The Artists group, with a distribution of 65.4% female and 34.6% male. This is almost a 10% increase over the distribution in the sample of the sexes and denotes a strong preference for female membership.

In summary, there appears to be a moderate-strength (Cramer's phi - 0.226) relationship between gender and cluster membership which, upon examination of each cluster, shows that proportional gender composition in each cluster is different than that of the sample (Slater & Tiggemann, 2011).

5.6: Parental Status

Our initial hypothesis was that the composition of household would be an influence on the ability for children to engage in activities outside of school is also the composition of the household. Parents, as the bearer of authority in most households, may have a significant impact on the activity choices of children (Veitch et al., 2010). However, our analysis concluded that the presence of a single-parent household had no relation to cluster membership in regards to lifestyle and transportation choices, as indicated in Table 4.6.

5.7: Limitations of the Study

The dataset used for this study, though robust, still lacked some information which could be improved. For example, the dataset only recorded activities, for most participants, on three to 4 days of the week. In order to generalize this across the entire week, this study standardized the amount of time spent engaging in each activity or transportation choice, assuming these activities would be somewhat equally disperesed. Take the example of a student which attends an hour-long art class twice a week. With the exception of the Artists cluster, every other cluster had less than one hour of weekly engagement in this activity. If the days of the week in which this art class occurred were not recorded, and this was the only significant art activity engaged in by this particular child per week, then the likelihood of that child being placed in Artists group was significantly reduced. There might be other characteristics that better place this child in another cluster but, if they do not, placement in a cluster other than Artists would likely constitute clustering error. Future studies should consider recording activity data for an entire week, rather than a combination of weekdays and weekends. This would provide a better representation of activities throughout the week and remove a potential source of bias through standardizing

A second limitation of this study is the use of GIS analysis in order to generate trips which were not in the dataset. A number of assumptions were made in producing this analysis, most notably the mean speeds of each mode of transportation. Though these were based off of reliable sources, they are only estimations. This does not account for varying speeds across different routes in different parts of the city, or account for day-to-day variations like traffic complications. The distance measurement these trips used was a straight-line analysis rather than a network analysis, which would have provided a more accurate estimation of the distance from origin to destination.

Another assumption occurred in the placement of all activities in the dataset recorded as 'playing' or similar being placed into the active unstructured play category. At best this is an educated guess, for the word 'Playing' could mean 'running in the woods' as much as it could mean 'Playing Chess'. This is a concern as it rendered all play activities other than active unstructured play too infrequent in incidence to use them in the analysis. This may have created an uneven bias towards this sort of play, resulting in the Mobiles cluster being less engaged in these activities than the categorized dataset represents.

The descriptive statistics also required some assumptions be made. The household location variable, though representative in a general sense of Toronto's built form, does not control with enough granularity for specific variations to be sure. This a proxy variable, offering more of a generalization of built form than a specific house-by-house characterisation of surrounding built form. There may therefore be mismatches in the dataset between urban and suburban forms which may have skewed the final descriptive statistics.

This cluster analysis was limited by several factors. One of these was the age range of 9 to 12 years old which was employed the dataset and was fundamental to its design. Though this tight age range strengthened the dataset, future analyses should examine a greater breadth of ages. A greater range of ages would not only open the analysis to the examination of more diverse activities, but would also provide a greater opportunity to generate profiles which reflect changes in age. As noted above, there was no statistical significance to cluster membership and this may have been due simply to the narrow mean range of the cluster analysis, with the greatest variation from 10.5 being only 0.11 years. There was likely not enough variation in the data set to make in trends apparent in the cluster solutions in regards to age.

Finally, the cluster solution for this analysis was itself only fairly robust, with a silhouette greater than 0 but not close to the ideal range of 0.05 or greater. This indicates that, while the clusters identified do exist, they are less defined than they might otherwise be. Increasing the veracity of these cluster solution might be explored through reducing the amount of information needing to be assumed by employing a different dataset, or possibly expanding or contracting the number of activity and transportation categories tested. This is something which can only be identified through continued experimentation and analysis.

6. Conclusion

This study's purpose was to conduct an exploratory analysis of transportation and lifestyle activity choices in relation to physical health outcomes among elementary school aged children in Toronto, Canada. Cluster analysis was used to identify students with similar lifestyle and activity choices. Five clusters were identified: Screeners, Artists, Athletes, Scholars and Mobiles.

These clusters were then compared on the basis of physical health outcomes as measured through daily minutes of Moderate-to-Vigorous Physical Activity. This association was measured through the use of an one-way analysis of variance test. The test indicated there was statistical significance to the physical health outcomes of the clusters. It also indicated that none of the five clusters, despite engaging in varying levels of sedentary and active activities, reached the recommended 60 minutes of daily MVPA (Tremblay et al., 2011). The cluster with the best physical health outcome was the Athletes, while the Screeners had the worst.

Through *chi*-square and ANOVA tests additional socio-demographic and built form analysis was carried out. These analyses indicated that there were correlations between household income, built form and gender when forming cluster membership. The Athletes cluster, with the best physical health outcome, had a higher than the mean Toronto household income, tended to have households in urban areas and was composed of more males than females. The Screeners cluster, with the worst physical health outcome, had a lower than mean Toronto household income, tended to have households in suburban areas, and had a greater concentration of females.

This study, despite some concerns and complications with the data used to inform it, has provided an initial foray into the interplay of children's lifestyle activity and transportation choices in connection to specific health outcomes. This study's results indicate that lifestyle activity and transportation choices may be studied in the same cluster analysis without one portion of the analysis overwhelming the other. The study's findings suggest that there are specific behaviours, such as participation in sports, use of active transportation and participation in active unstructured play, which tend to occur in concert with greater overall physical activity accumulation. It also indicates a possible relationship between sedentary activity choices, low overall transportation use and worse physical health outcomes.

Given the uneven balance of variables used in the final analysis of six lifestyle activities to two transportation choices, dividing transportation activity categories into multiple mode choices could lead to intriguing results. Particularly dividing bicycling and walking, along with public transportation from personal vehicle use, might help to construct a better activity profile leading to health outcomes. It would also be beneficial to investigate a rural rather than urban/suburban setting in order to identify any additional characteristics of resultant clusters. With regard to this last suggestion, any built form correlation should be more robust, examining household by household built form rather than generalized geographic areas.

As a final note, this research was only exploratory and did not estimate any statistical model where adjusted correlations between socio-ecological influences were examined. Future research should explore these relationships more closely, which will produce a more robust analysis of conclusions regarding influences and causalities in cluster formation and physical health outcomes.

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