8-19-2014 12:00 AM

Examining the Influence of Environmental Opportunities and Exposures on Children's Sleep Duration

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A thesis submitted in partial fulfillment of the requirements for the degree in Master of Arts

EXAMINING THE INFLUENCE OF ENVIRONMENTAL OPPORTUNITIES AND EXPOSURES ON CHILDREN'S SLEEP DURATION

(Thesis format: Monograph)

By:

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Master of Arts

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Abstract

This research aims to fill a void in knowledge on how certain characteristics of the built and natural environments may impact children's sleep duration. Data were collected on a sample of 614 children (aged 9-14 years) drawn from 22 elementary schools throughout the City of London, Ontario, Canada. Participants completed the STEAM (Spatial Temporal Environmental and Activity Monitoring) protocol which involved completion of a survey, daily activity diary, and tracking the time they spent in different environments with a portable Global Position System. This thesis incorporates an innovative analytical approach which uses two Geographic Information System techniques to examine if and how different neighbourhood level environmental opportunities and exposures have an influence on children's sleep duration.

Hierarchical multiple linear regressions were used to explore the relationship between children's sleep duration and neighbourhood level environmental features. Analysis found that green space opportunity positively impacted children's average sleep duration when measured by Normalized Difference Vegetation Index. Additionally, with each percent increase in amount of time spent around park spaces each day, children's sleep duration increased by 13 minutes. From these findings, policy makers, educators, and parents can help in promoting a greater amount of time to be spent in parks for healthier sleep durations in children.

Keywords

Children, Sleep, Green Space, Natural Environment, Built Environment, Neighbourhood, Opportunity, Exposure, GIS

Acknowledgments

This thesis could not have been completed without the immense support and guidance from my supervisor Dr. Jason Gilliland. Your expertise and imagination are incredible and I wouldn't be where I am today without you. Thank you very much for the opportunity you gave me.

There are not enough words in to express my gratitude towards Sandra Kulon. Your patience, knowledge, and skills are truly remarkable. You are a rare gem, always willing to help others and teach them the ways of GIS. I appreciate and value all the time you have taken to teach me, I have learned so much from you.

To all the members of the HEAL lab: Lucie, Sarah, Doug, Christine, Don, Rick, Andrew, Mark and many others I want to thank you for all your time you have put into data collection and proof reading. The huge data set that we are fortunate enough to have is because of all of you and I want to express my appreciation for all the help and time you have put in.

I would like to thank Jamie Seabrook for your brilliant expertise with statistical analysis. Your assistance has been hugely appreciated. Graham Reid, your knowledge, skills, and insights have been a great asset to this thesis. I would like to thank you for all your guidance.

Mark, I would like to thank you for being my rock. Your calm and collective personality, multiple visits to London, night phone calls, and presence has meant everything to me. You are such a generous, patient, and encouraging person and I am so lucky to have you in my life.

To my family – thank you for all the love and support you have given me throughout my life. You have always been there for me and I wouldn't be where I am today without you.

To all my friends, you know who you are. The nights out, camping trips, bon fires, baseball games, Settlers of Catan nights, and family dinners have been a blast. You have all made this journey memorable and highly enjoyable.

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Chapter 1 Introduction

1.1 Research Context

Adequate, quality sleep for children is increasingly recognized as a public health concern as more studies indicate that a considerable number of school-aged children are not getting enough sleep (Carskadon, 1990; Loessl et al., 2008; Smaldone et al., 2007). Although sleep plays a fundamental role in physical and cognitive well-being, sleep is increasingly short in duration, sleep schedules are often inconsistent and/or delayed, and daytime sleepiness is becoming more common among children (Hasler et al., 2004; Sadeh et al., 2003). Research has confirmed the fundamental role of sleep on the everyday lives of individuals, including the reduction of stress (Hall et al., 2004), regulating emotions (Fredriken et al., 2004), improving cognitive performance (Dewald et al., 2010; Sadeh, Gruber & Raviv, 2003), strengthening the immune system (Carney & Manber, 2009), and the reduction of daytime fatigue and sleepiness (Sadeh, Raviv & Gruber, 2000). Sleep is also increasingly recognized as important for children's mental and physical well-being (Hasler, 2004; Smaldone et al., 2007). For school-aged youth, disrupted or inadequate sleep can result in daytime fatigue, which can impact learning, attention, and mood (Cain & Gradisar, 2010). It has been reported that 10-45% of Canadian children have some form of sleep disorder, varying from insomnia to sleep walking (CIHR, 2012).

Over the past few decades, emerging empirical research has explored the influence of neighbourhood settings such as surrounding land use mix, transportation infrastructure, and recreational opportunities on children's physical and mental well-being. These well documented relationships have been explored within many fields of study, including geography, environmental health, public health, psychology, and epidemiology. Growing evidence suggests that exposure to more natural environments, for instance green spaces and increasing degrees of greenness, can bring positive health benefits to individuals, especially children (Roe & Aspinall, 2011; Schell, Cotton & Luxmoore, 2012). Greenness is an indication of the level of vegetation, which can range from dense forested parks to sparsely-landscaped streets (Almanza et al., 2012). Found health benefits from greater exposure to green spaces include increased mental health and well-being (Berman et al., 2012; Jutras, S., 2003), heightened physical activity levels (Annerstedt et al., 2012), a reduction in mental fatigue leading to an increased level of cognitive restoration (Norton, C., 2010), and increased relaxation and reduced stress (Beil, K & Hanes, D., 2013; Beltramini & Hertzig, 1983; Beukeboom et al., 2012; Ryan et al., 2010).

Given the evidence that natural environments help aid in the reduction of stress (Beukeboom et al., 2012; Norton, C., 2010; Ryan et al., 2010), and stress is known to negatively impact children's sleep (Carney & Manber, 2009; Hall et al., 2004) it stands to reason that greater exposure to natural environments, such as green spaces, will positively influence children's sleep duration. The link between the relative influence that greenness has on children's sleep duration and quality is missing within the existing literature which examines the health benefits of green space. If exposure to green spaces significantly impacts children's sleep duration over alternative land use mixes (i.e. commercial, institution, industrial, agricultural, recreational, and residential space) and is influential in positively impacting children's sleep duration, then the creation or preservation of natural environments and green spaces should be further prioritized by city planning and policy makers, as green spaces are modifiable attributes to the built environment. The purpose of this thesis is to address this current gap in knowledge.

Although the study of children's sleep is primarily situated in medicine, in the fields of pediatrics and psychology (Reid et al. 2009; Coulombe et al., 2010), it also has a place in the field of geography. Examining the influence that surrounding environmental features has upon children's health can be positioned in several sub-fields of geography, including urban geography, children's geography, health geography, Geographic Information Systems, transportation geography and others. In particular, this thesis contributes to children's geography, health geography, and Geographic Information SystemsResearch Objectives.

This thesis intends to add to the expanding body of knowledge linking children's health and well-being with greater opportunity or exposure to green spaces. The principal objective of this thesis is to explore the benefits that green space opportunities and exposures have upon children's sleep duration. In order to explore this relationship, the overarching thesis research question is: **"to what extent do green spaces and other built environmental features impact children's sleep duration?"** To assist in answering this main research question, the following supplemental questions will also be explored:

1. Does greater availability of green space in an individuals' neighbourhood have an impact on the duration of sleep?
2. What physical environmental features (including natural and built) surrounding the child's home neighbourhood have an influence on children's sleep duration?
3. Is children's sleep duration impacted by their daily exposure to green space?

These questions will be answered using two different approaches with the aid of Geographic Information System (GIS). These methods will be further explained in Chapter 3 (section 3.2).

1.2 Study Area and Study Population

For this thesis, a sample of 614 children aged 9-14 years was selected from 22 elementary schools to participate in the study. The school locations were of stratified socio-demographic status and built environment features throughout the City of London. The geographic area of The City of London is a mid-sized Canadian city. This makes an ideal geographic area for two reasons: it provides for a cross-section of children coming from differing built environments and having differing socioeconomic status; and secondly it will provide local and contextually appropriate results for municipal policymakers. In order to maximize potential application of the findings, the city planner of the City of London is a co-investigator on the larger research project under which this thesis was conducted. Schools within the City of London were selected in order to capture a mix of both urban and suburban neighbourhood types of high, middle, and low income levels. A map of the schools locations is displayed in Figure 1.

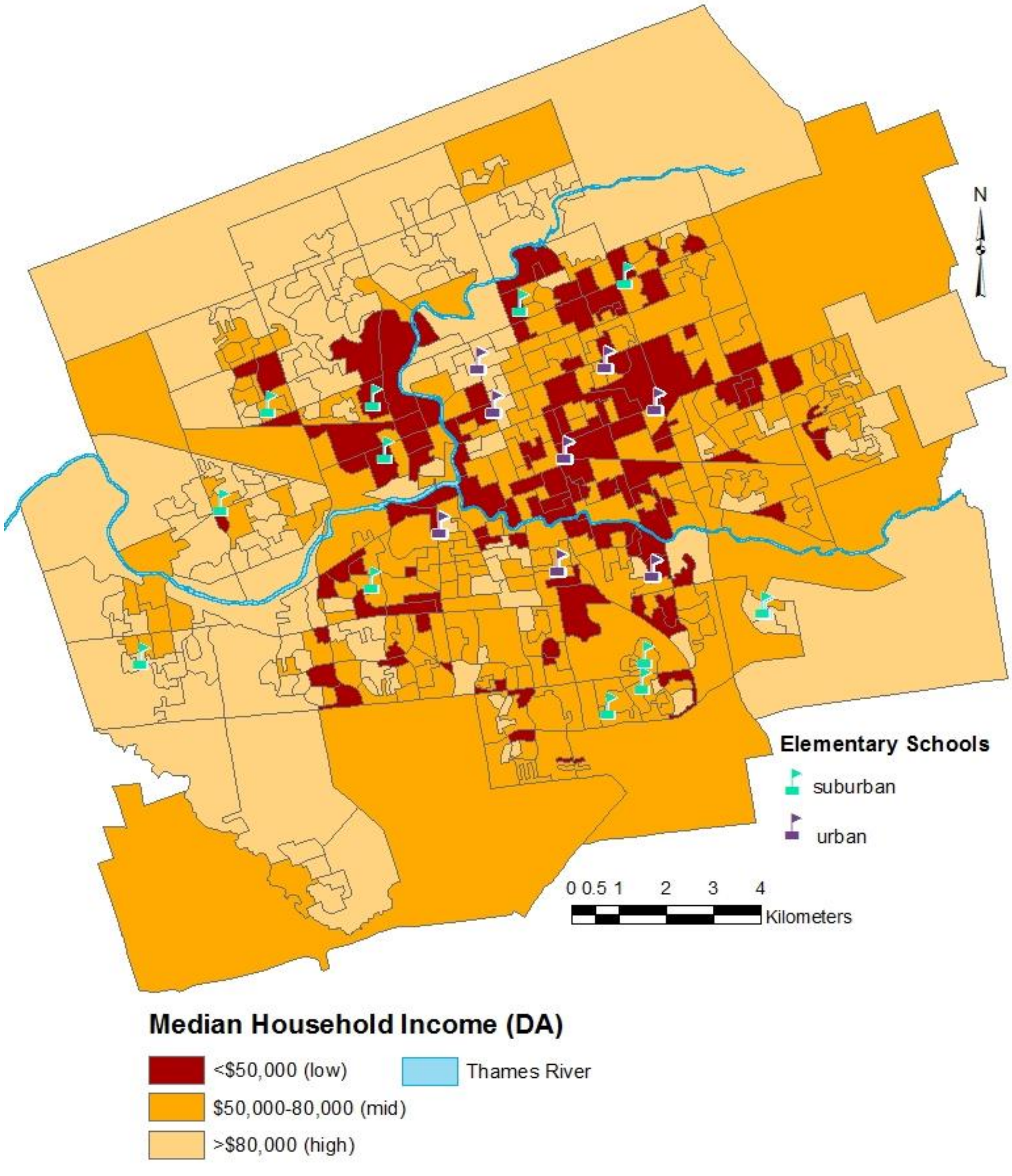

Figure 1: Locations of the study schools in the context of neighbourhood socioeconomic status. The colour of the school represents whether the school is situated in an urban or a suburban neighbourhood. *Note: only 20 schools appear as two schools were sampled twice.* (Statistics Canada, 2006; City of London, 2011).

1.3 Theoretical Framework

The theoretical framework which guides this thesis is the *Social-Ecological Model of Health Behaviour,* which explores the various factors which play a role in influencing individual health (Stokols, 1996). The core concept of the model is that there are multiple levels which can have an influence on individuals' health, including intrapersonal, interpersonal, organizational, community, physical environmental, and policy (Sallis et al., 2008). Thus, the ecological model offers a framework for understanding the various and interacting determinants of health behaviour (Sallis et al., 2008). A major strength of this model is that it acknowledges the multiple levels which influence, and are influenced by, individuals and their daily interactions (Sallis et al., 2008). The model also seeks to explain how individuals' transactions with their environment, both physical and sociocultural surroundings, offer constraints and opportunities for health-promoting and demoting behaviours (Lachowycz & Jones, 2013; Sallis et al., 2008; Stokols, 1992). This suggests that various levels of environmental features can influence children's health behaviours (for example their sleep duration). The primary environmental factor which will be explored for this thesis is neighbourhood level green space opportunities and exposures. Figure 2 explores various levels (intrapersonal, interpersonal, neighbourhood/institution, and macro level/policy) and the factors within each level (used within this study) which could all have an influence on children's sleep duration.

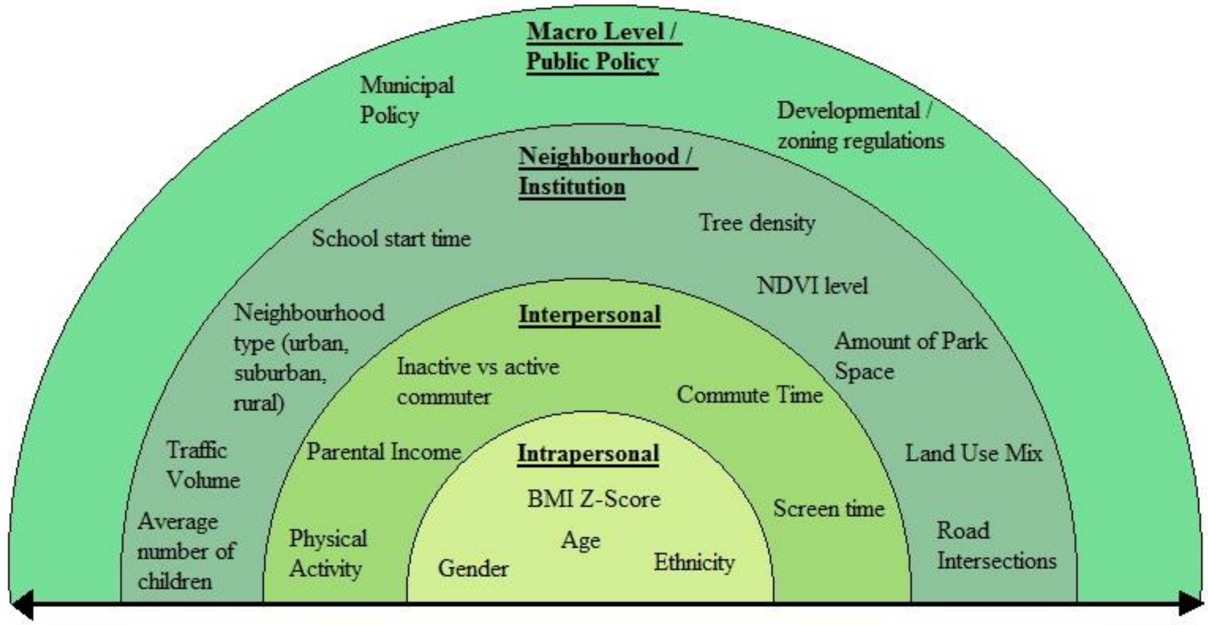

Figure 2: Socio-economic framework for understanding the various levels which influence children's sleep duration (adapted from Fitzgerald & Spaccarotella, 2009).

It is evident from this model that an individual is influenced by other groups and levels which surround them (for example environmental features in their neighbourhood). The arrow, at the bottom of the diagram, spreads across all of the levels of interaction, suggesting that all of the factors encompass and interact across the different levels. For example, it is an individual's (or parent's) choice whether to commute to school actively or inactively; however, this choice is also influenced by the surrounding environment and the potential barriers which would restrict the child from being able to walk to school. If applied to green space opportunities, a hypothetical interaction could be that living in a neighbourhood with a greater amount of green space, such as more park space, would support individuals, for instance, to obtain healthy amounts of sleep.

1.4 Thesis Format

This thesis is presented in a monograph format comprised of six chapters. Chapter 2 presents the literature review summarizing key evidence on the relationship between the benefits of green space exposure and children's health as well as factors which have been found to help improve or hinder sleep duration. Chapter 3 describes the data collection procedures and techniques used to answer the research questions at hand. Chapter 4 presents the results of the neighbourhood level examination of the impact of individual and environmental factors on children's sleep duration. Chapter 5 presents the results of individual daily green space exposure and how it impacts sleep duration. The final chapter connects the results found in the two result chapters and offers implications of the research and potential steps forward.

Chapter 2 Literature Review

This chapter is intended to review relevant literature regarding the reported health and well-being impacts of green space on children and factors which have been found to influence sleep duration. The literature review will first outline the foundations to exploring the benefits of green space, will then discuss the possible benefits of exposure to green spaces for children's psychological and physical health, and will then discuss potential factors which have an impact on children's sleep duration.

2.1 Foundations of the Benefits of Green Space

Benefits of the availability and experience of "green" environments on individuals' physical and mental well-being can be studied largely from the context of two dominant theories: Ulrich's Stress Reduction Theory (SRT) and Kaplan and Kaplan's work on Attention Restoration Theory (ART) (Kaplan & Kaplan, 1989; Ulrich, 1963). Ulrich's research on SRT is primarily concerned with the reduction of stress by better understanding mental, emotional, and physiological components of strenuous and exhaustive states. An essential aspect of Ulrich's theory is that the natural environment offers a calming, stress reducing effect upon individuals because it provides a revitalizing stimulus that produces positive emotions and a reduction in neurophysiological arousal (Ulrich, 1979, 1984). It is suggested that viewing or being exposed to natural environments following stressful situations (such as school) should shift one to a more positive emotional state with "decreased levels of physiological arousal" (Ulrich et al., 1991, p 208). Findings suggest that this response occurs because natural environments are associated with more positive experiences as opposed to human built environments which tend to hinder recovery from stress (Ulrich et al., 1991).

Kaplan and Kaplan's work goes even further by concentrating on what exactly nature does for individuals under varying circumstances (1989). Their Attention Restoration Theory suggests that natural environments, such as green spaces, offer a restorative measure to the reduction of mental fatigue (Kaplan & Talbot, 1983; Kaplan & Kaplan, 1989). Much of modern society's work requires increased focus and *directed attention*, which refers to a task which is not particularly interesting to the individual thus requiring increased mental effort and maintained focus, leading to mental fatigue (Kaplan and Kaplan 1989; Kaplan 1995). Because much of modern society's work requires this type of attention, it can lead to increased levels of exhaustion. ART postulates that qualities in the environment must encourage attention restoration and suggests that natural environments often have such restorative qualities (Kaplan, 1995). In Kaplan and Kaplan's book, *The Experience of Nature,* the relationship between the natural environment and individuals is explored. Within the book, the term 'restorative environment' was coined – which is an environment where recovery of mental energies and effectiveness is heightened (Kaplan & Kaplan, 1989).

2.2 Benefits of Green Space Exposure for Children

A diverse range of studies seeks to examine how access and exposure to green space and natural settings positively contributes to a range of children's health benefits, including but not limited to, stress reduction (Wells & Evans, 2003), increased concentration and school achievement (Wells, 2000), improved restoration (Laumann et al., 2001), and higher levels of physical activity (Almanza et al., 2012). These relationships have been explored in a variety of forms, including outdoor educational programs (Gotch & Hall, 2004), wilderness programs (Kellert and Derr, 1998; Norton, 2010), play settings (Soderstrom et al., 2012), school settings (Han, 2009; Martensson et al., 2009), and green space within neighbourhoods and urban areas (Almanza et al., 2012; Collins et al., 2012). For the purpose of this thesis, these health outcomes are divided into two broad categories for more thorough discussion: psychological and physical benefits. This dichotomy is commonly presented within literature with psychological benefits typically gleaned from exposure to green space and the social interactions which accompany it and the physical health benefits naturally stemming from the various physical activities demonstrated within green spaces (Bowler et al., 2010; Lachowycz & Jones, 2013). Although limited in research, the benefits regarding individuals' sleep will also be examined as this is the focus for this thesis.

2.2.1 Children's Psychological and Mental Well-being Benefits

Exposure to natural environments, such as green spaces, can lead to a diversity of positive psychological, emotional, and mental well-being outcomes, whether this comes from a view of nature from a window, a painting of a natural element, or being immersed within a natural setting. For the purpose of this section three categories will be explored with regards to existing literature examining children: self-esteem and mood, restoration, and stress reduction and calming effects.

Self-esteem & mood

Exposure to natural settings can bring about increases of self-esteem and mood for children (Barton & Pretty, 2010). Exposure time of five minutes was found to have the greatest changes, with smaller positive enhancements for one hour, half a day, and full day exposure times. Additionally, all measured green environments (urban green space, countryside, waterside, wilderness areas, and woodlands) help to improve both self-esteem and mood states, with the additional presence of water producing the greatest improvement.

Taylor et al (2002) rated the amount of nature viewed from a high-rise window (on a four point scale) on self-discipline in inner-city girls. A 20% variance in score on the combined self-discipline index was accounted for by view. Lower self-discipline ratings were reported within girls with less greenery from their window view.

Kellert and Derr (1998) conducted a large study of over 400 youth who were surveyed and interviewed to report on experiences following a wilderness challenge program. Increased levels of personal autonomy, improved self-concept, improvement in interpersonal skills, and greater capacity for taking control were all observed. These findings suggest that exposure and contact with green space areas can have benefits to children's development. David Sobel (1993) emphasized the importance of contact with nature for personality formation during middle childhood. Based on empirical studies of children's interactions with nature, Sobel concluded that: "Middle childhood is a critical period of development of the self and in the individual's relationship to the natural world. The sense of wonder of early childhood gets transmuted in middle childhood to a sense of exploration. Children leave the security of home behind and set out… to discover the new world" (1991, p. 159).

Restoration

Building off of Kaplan and Kaplan's ART, researchers have established different ways of measuring restoration. Laumann et al. (2001) developed a rating scale to measure the four key components of restorative environments as outlined in ART (being away, extent, fascination, and compatibility). A group of university students were instructed to imagine themselves first in a familiar natural environment or urban environment which they rated on a unipolar scale as a way to describe their experience of that environment. They then watched videos of parks, forests, water bodies, a city, and a mountainous area and were asked to rate that experience on a unipolar scale to describe the experience following the viewing. Analogous to what Kaplan and Kaplan predicted, natural environments scored higher on the rating scale than urban/city environments on each of the measures (Laumann et al., 2001). A similar study examined whether greater views of greenness affected children's ability to cope with poverty and other life issues (Kuo, 2001). With greater levels of surrounding green, children were able to pay greater attention and dealt with major life issues easier than those with more barren surroundings. Taylor et al (2001) explored whether ART could also be applied to children and their ability to deal with Attention Deficit Disorder. Parental surveys were conducted targeting children's attentional functioning in a variety of play settings. Greener settings were reported to be the most effective in enhancing attention for children. Furthermore, it was conveyed that Attention Deficit Disorder symptoms appeared less severe with greener play settings (Taylor et al., 2001).

Stress Reduction & Calming effect

Experiencing green space and viewing natural elements help reduce stress through a number of mechanisms, including a sense of control and feeling of escape (Ulrich et al., 1991). These mechanisms have been found in a variety of settings including: laboratory (Ulrich & Simons, 1986), health care environments (Dijkstra et al., 2006), and school environments (Matsuoka, 2010). Research has found that natural environments are perceived as more attractive than built environmental features (Ulrich et al., 1991); thus, psychological well-being is significantly associated with perceived attractiveness of environmental elements (Van den Berg et al., 2003). From these findings, researchers argue that individuals' prefer natural environments because of the potential for reduction of stress (Beukeboom et al., 2012).

Ulrich (1979; 1981) uses a variety of empirical evidence to show that viewing green space or other natural settings or elements reduces stress levels. In one study, students who experienced mild exam-related stress reported their stress levels before and their recovery levels after viewing slides of either nature scenes or city views lacking nature (Ulich, 1979). Natural scenes captured attention more effectively and fostered greater stress recovery, which was measured by lower levels of fear and higher levels of positive affects (Ulrich, 1979). Another study found that viewing scenes consisting of natural settings sustained greater attention and produced higher positive feelings than did viewing more urban scenes (Ulrich, 1981). These self-reports were consistent with objective measures of brain electrical activity which suggested that participants felt more relaxed during viewings of natural scenes versus urban scenes.

Heerwagen (1990) explored the effects of adding physiological measures to investigate the potential stress-reducing effects in a health care setting by measuring heart-rate and self-reported ratings of stress when a mural illustrating a view of mountains, trees, and open grass areas were added to a waiting room. Results confirmed that patients felt less stressed on days when the mural was displayed (Heerwagen, 1990). Wells & Evan (2000) studied a group of rural children and found that those with more nature surrounding their home rated themselves higher on a global measure of self-worth than those with less nature. It was suggested that this surrounding nature buffered the effects of stressful life events on the children's psychological distress. Korpela's (1992) study of 337 rural children, aged 8-11, found that even among those who were exposed to a reasonable amount of natural green space in their everyday lives, those with even greater exposure saw more stress-reducing improvements (Korpela, 1992). The study reported that regardless of parental socio-economic status, the greener the home surroundings, the more resilient children appeared to be against stress and adversity. This protective effect was found greatest for children who experienced higher levels of stressful life events.

Nature has been found, on numerous occasions, to make individuals feel at ease and relaxed. Dating back to 1865, Fredrick Law Olmsted claimed that for those experiencing stress "viewing nature employs the mind without fatigue and yet exercises it; tranquilizes it and yet enlivens it; and thus, through the influence of the mind over the body, gives the effect of refreshing rest and reinvigoration to the whole system" (from Ulrich et al., 1991). Alternatively, physical activity has been found to provide psychological benefits, such as stress reduction and enhance well-being. Importantly, "stress reactions may be reduced with exercise, which rids the body of some of the fighting and wakefulness hormones. Exposure to daylight may reduce stress reactions by adjusting hormone levels, especially cortisol and melatonin" (Gran & Stigsdotter, 2003, pg 3), thus allowing the individual to be able to relax and sleep.

2.2.2 Children's Physical Benefits

Physical inactivity and sedentary behaviours are helping to cause rising obesity rates in Canadian children. Children's overweight and obesity rates have increased from

13% to 26% between 1978 and 2004 (Healthy Canadians, 2011). As a way to counteract these trends, the promotion of the environment as a positive influence on physical activity levels has been suggested (Jones et al., 2007). This section will address how physical activity and obesity levels in children are fostered by the environment through opportunities and experience of green spaces.

Children's Physical Activity Levels

The most commonly reported physical benefit of green space exposure on children are the positive effects on physical activity levels (Almanza et al., 2012; Macintyre et al., 2008; Van den Berg et al., 2003; Wheeler et al., 2010). "Green exercise", which involves activity that takes place outside with the presence of nature (e.g. playing tag), has been reported to generate positive health outcomes (Barton & Pretty, 2010; Ulrich et al., 1991; Van den Berg et al., 2003), which come from as little as five minutes of nature exposure (Barton & Pretty, 2010). Alterations to the built environment to offer green space opportunities allows for beneficial green exercise, such as biking, sports or playing tag. The provision of open spaces, such as parks and other green spaces, for recreation may offer a vital location to be active (Macintyre et al., 2008). Almanza et al (2012), equipped 8-14 year olds (n=208) with GPS and accelerometer units to explore relationships between children's physical activity levels and neighbourhood design features. It was found that greater exposure to greenness was significantly related to higher levels of physical activity. In another study, children exposed to 15-20 minutes of daily green space activities were reported to engage in 2.11 times more moderate to vigorous physical activity (MVPA) than children who were reported to have no exposure

(Macintyre et al., 2008). Children who experienced greater than 20 minutes of green space exposure engaged in 4.72 times the daily rate of MVPA (Macintyre et al., 2008).

Grigsby-Toussaint and colleagues (2011) investigated the association between the level of neighbourhood greenness and children's physical activity levels. With each increase in neighbourhood greenness, as measured by NDVI, an increase of physical activity time would increase by about three minutes a day. Children who resided in neighbourhoods of lower levels of greenness were less likely to spend time outdoors participating in active or inactive play (Grigsby-Toussaint et al., 2011). Findings were alike in a study conducted with children aged 6-11 years, where physical activity levels were significantly associated with the percentage of green space within their neighbourhood (de Vries et al., 2007).

Green exercise clearly provides positive physical benefits, but simply being outdoors is also beneficial. Physical activity levels, as measured by accelerometer, and spatial locations, as measured by GPS, were recorded in a sample of 1010 children aged 10-12 in England (Cooper et al., 2010). It was found that time spent outdoors was significantly associated with children's physical activity levels. Physical activity was approximately 2.5 times higher outdoors than indoors (Cooper et al., 2010). Correspondingly, in a study of 10-12 year olds (n=548) there was a significant association between the time spent outdoors on weekdays and weekends with increased levels of MVPA (Cleland et al., 2008). An increase of 27 minutes per week for girls and 20 additional minutes per week for boys of MVPA was recorded with each additional hour spent outdoors (Cleland et al., 2008). Research consistently shows that children who spend more time outdoors versus indoors engage in increased levels of physical activity. If outdoor time is spent within green space areas, even higher levels of physical activity are reported (Cleland et al., 2008).

Barriers to adolescents' physical activity include urban form and the built environment which can restrict the opportunities for accessing areas for physical activity (Brownson et al., 2005). Literature has reported an association between neighbourhood design and individuals' health and active living (Saelens et al., 2003; Sallis et al., 2009). With the increasing trend to live in urban centers (Barton & Pretty, 2010), there is a growing importance to access green spaces for individuals' enhanced quality of life. This is imperative as it has been found that individuals with greater access to green spaces are more likely to utilize them (Roemmich et al., 2006).

Childhood Obesity

Rates of overweight and obesity among North American children are increasingly becoming a public health concern (Shields, 2006). Children's increased exposure to greener environments helps moderate obesity risk by encouraging higher levels of physical activity (Grigsby-Toussaint et al., 2011; McCurday et al., 2010). An inverse relationship was reported by both Bell et al (2008) and Liu et al (2007) between children who are overweight and increased neighbourhood greenness. Moreover, children who resided in greener neighbourhoods were less likely to have an increased Body Mass Index (BMI) z-score two years later as opposed to children living in less green neighbourhoods (Bell et al., 2008). Corresponding to this finding, individuals who resided farther from green spaces were more likely to be overweight or obese (Coombes et al.,2010). Closer proximity to greater infrastructure (e.g. soccer fields, basketball nets, and play structures) and the number of physical activity and recreational facilities was associated with lower rates of obesity in children (Coombes et al., 2010; Motl et al., 2007; Gordon-Larson et al., 2006). A potential rationale for this relationship is that greener neighbourhoods are more likely to be aesthetically attractive and encourage a greater variety of physical activity types, and therefore motivate increased activity outdoors for children, reducing the likelihood to be overweight or obese (McCurday et al., 2010).

2.2.3 Benefits to Sleep Duration

Given the evidence which highlights the importance for today's youth to spend time exposed to natural environments, it is imperative to further explore the potential positive benefits of natural environments on children's mental health and wellbeing. Because nature and related environments, such as green spaces, have shown to reduce stress (Kaplan & Talbot, 1983; Gran & Stigsdotter, 2003) and have a soothing effect on individuals (Gran & Stigsdotter, 2003), exposure to these environment types may also have a positive association with children's sleep. Although there is a growing body of literature documenting a connection between green space and physical and mental well-being (as shown above), little is known about the direct connection between exposure to green space and sleep particularly with regards to children. Based on previous research, therefore, this thesis hypothesizes that with increased exposure and time spent immersed within green space areas a positive improvement should be observed with children's sleep habits.

2.3 Factors Impacting Children's Sleep Duration

Today's society has seen an increasing trend towards shorter sleep durations (Hasler et al., 2004; Sadeh et al., 2003). There is strong evidence that globally, children fail to get enough sleep (Reid et al., 2002; Yamaguchi et al., 2000). Associations have been made between shorter sleep durations and morbidity and mortality (Ferrie et al., 2007), self-reported well-being (Steptoe, Peacey & Wardle, 2006), children's learning, memory, and other neurobehavioural functions (Sadeh et al., 2003), obesity, type 2 diabetes, and respiratory disorders (Gangwisch et al., 2006; Yaggi, Araujo & McKinlay, 2006). Following the ecological model, this section divides factors that influence sleep into three categories: individual and behavioural, household, and environmental level factors.

2.3.1 Individual and Behavioural Level Factors

The majority of known factors which limit or restrict a child's sleep duration are individual level factors. Studies have reported a significant decrease in the length of sleep as age increases (BaHammam et al., 2006; Dollman et al., 2004; Hasler et al., 2004; Iglowstein et al. 2003; Krueger & Friedman, 2009; Spilsbury et al., 2004). Studies have shown that respondents who reported 'short' sleep durations tended to be older than those reporting 'long' sleep durations (BaHammam et al., 2006; Iglowstein et al. 2003; Krueger & Friedman, 2009). Supporting this trend, Dollman et al (2007) found that adolescent sleep duration would decrease by approximately 14 minutes with each additional year of age.

Increased attention has been directed towards children's nutritional status and body weight in relation to the length of sleep they receive. Obesity or higher BMI levels is one of the most consistently reported associations linked with shorter sleep duration (Bjorvatn et al., 2007; Hasler et al., 2004; Hitze et al., 2008; Krueger & Friedman, 2009; Lanningham-Foster et al., 2006; Nixon et al., 2008). A longitudinal study tested whether adolescents who slept less, went to bed at a later time, or got up earlier had a higher BMI level at the second time interval (five years later) (Snell et al., 2007). Those who slept less than 8 hours a night correlated to a higher BMI while those who slept between 10 and 11 hours correlated with a lower BMI and not being overweight at the second time interval. An association was reported between adolescents with later bed times and an increased likelihood of being overweight. For each additional hour that one stays up at night before sleep, the BMI value would increase by 0.12; however, for each additional hour of sleep in the morning, the BMI value would decrease by 0.12 (Snell et al., 2007).

Mixed results have been found with regards to the influence that ethnicity has on the amount of sleep obtained by individuals. Lauderdale and colleagues (2006) reported that 'Blacks' were found to have overall lower mean sleep duration and longer amounts of time taken to fall asleep than their 'White' counterparts, while Riedel et al (2004) found the opposite to be true. Hale & Do (2007) reported that individuals of visible minority status have greater odds than non-visible minority individuals of obtaining lower and higher than normal sleep durations.

The amount of time spent in front of a screen is also reported to negatively impact the amount of nightly sleep received. Research shows a positive correlation between adolescents who have a television or computer in their bedrooms and later bedtimes and a shorter duration of sleep during the weekday and the weekend (Li et al., 2007; Olds et al., 2006; Van den Bulck, 2004). For each additional hour of television viewing per day, children slept 5.89 minutes less per night (Bottino et al., 2012). Similar to this, another study found that for children aged 10-13 years old, for every extra hour of time spent in front of a screen, a decline in about 10 minutes of sleep was recorded (Olds et al., 2006). Greater than two hours of television viewing a day was found to be the predominant risk factor for all sleep disorders (Liu et al., 2007).

Increased levels of stress have been found to negatively impact sleep quality (Carney & Manber, 2009; Hall et al., 2004; Mezick et al., 2009; Vgontzas et al 2008; Williamson et al., 1995). A diverse range of stressors encountered from the daily environment have been found to result in reduced sleep duration, such as failing a grade, parental separation/divorce, and death of a family member or friend (Williamson et al., 1995). In a study conducted in 2008, distressed individuals were found to have a reduction of sleep duration than less distressed individuals (Vgontzas et al). Similarly, another study found that individuals who reported more cases of stressful life events were associated with increased sleep fragmentation and duration (Mezick et al., 2009).

2.3.2 Household Level Factors

Certain household level factors have been found to impact children's sleep duration. Studies report that parental socioeconomic status (SES) is a determinant of the length of sleep received by children. Literature suggests that a reduction of sleep is more pronounced for those of lower SES backgrounds than those of higher SES (Anderson et al., 2009; Dollman et al., 2007; Hitze et al., 2008; Krueger & Friedman, 2009; Owens et al., 2006). In a study conducted with inner city adolescents, it was reported that SES related matters, for example perceived safety due to their surrounding environment, had a negative influence on sleep habits (Owens et al., 2006). Sleep duration was shorter for those whose mothers had lower educational levels compared to those whose mothers had higher levels (Anderson et al., 2009; BaHammam et al., 2006). Having a younger sibling was reported to increase the length of sleep received (Nixon et al., 2008). Nixon and colleagues (2008) found that adolescents who had younger siblings slept an additional 11.7 minutes than the rest of the sampled group. No significant difference was reported for those with older siblings (Nixon et al., 2008).

2.3.3 Environmental Level Factors

In addition to individual, behavioural, and household level factors, a child's environmental surrounding may have a large impact on the quality or duration of sleep they receive. According to the World Health Organization the social determinants of health framework theorizes that the conditions in which "people are born, grow, live, work and age" plays a role in one's well-being (World Health Organization, 2013). Although not extensively explored for the role of sleep, environmental factors, such as ones' surrounding residential neighbourhood, may influence this pattern.

Literature suggests that adolescents who reside in less economically wealthy settings are increasingly more vulnerable to social disorders (Ross & Mirowsky, 2001), such as violence and crime, which can negatively influence their mental well-being (Leventhal & Brooks-Gunn, 2003), and thus, disrupt their sleep (McEwen, 2012).

The level of noise pollution within neighbourhoods from aircrafts, railway, and vehicles is another factor that influences sleep. Studies report higher sleep disturbances and sleep fragmentation occurring due to road traffic noise (Bluhm et al., 2004;

Kluizenaar et al., 2009). Bluhm et al. (2004) found that 23% of their population sample reported sleep disturbances occurring frequently due to road traffic noise.

Seasonality has been reported to have a significant effect on adolescent's sleep duration. Research suggests that the winter season has the longest sleep duration, followed by autumn and spring, with the summer season having the shortest sleep duration (Nixon et al., 2008).

Studies have indicated that the level of urbanicity can have an impact on sleep duration. It was found that a higher percentage with shorter sleep durations tended to reside in more central city environments compared with those residing in more rural environments (Hale & Do, 2007). Sleep durations were reported to be lower in areas of higher urbanicity with higher population densities, therefore concluding that residing in more urban environments is associated with shorter sleep duration (Bottinco et al., 2012).

For children, school environments are an externally imposed constraint on the number of hours available to sleep, whether due to early school start times or school schedules (Hansen et al., 2005; Owens et al., 2010; Szymczak et al., 1993; Wolfson & Carskadon, 1998). Owens et al (2010) found that later school start times increased the students overall sleep duration. Likewise, Wolfson & Carskadon (1998) report that earlier school start times impose constraints on students sleep duration, as they constrict the time available for sleep. In one study, students kept sleep diaries in the summer and fall to determine how much their sleep patterns changed with the start of school (Hansen et al., 2005). It was found that all students within the study, lost approximately two hours of sleep per night on school days.

2.4 Children's Sleep and Green Space

An Australian 45 and up national study explored whether those, with greater *access* to green space areas had longer sleep durations (Astell-Burt et al., 2013). Individuals who obtained 8 hours of sleep were found to reside in neighbourhoods with a greater percentage of green space while individuals who obtained less than 8 hours tended to reside in neighbourhoods of less overall green space coverage (Astell-Burt et al., 2013). The quality of outdoor child day care environments was explored and found that with higher quality outdoor environments, assessed by Outdoor Play Environmental Categories (OPEC), longer sleep durations were recorded among children attending the day care (Soderstrom et al., 2012). Children attending lower OPEC rated day care centers slept on average of 10.7 hours a night, while those attending higher OPEC rated day care centers reported an average of 11 hours of sleep per night (Soderstrom et al., 2012). What is lacking in these previous studies is the daily amount of time children have spent immersed in green spaces and how that relates to their daily sleep durations and habits. No research to date has investigated the impact that exposure to green space or natural environments has upon children's sleep duration. This is why the present study is of fundamental importance as it will be filling this gap of knowledge.

Well documented within the literature are children's preferences for outdoor / green space settings (Korpela, 2002; Pellegrini, 1992; Wells and Evan, 2003). Child participants identified natural and residential environments as their favourite places and linked natural favourite places to restorative experiences (Korpela et al., 2001). Lynch (1977) found that when he asked city-dwelling children what they would add to their city, children advocated for more trees to be planted. "The hunger for trees is outspoken and seemingly universal" (Lynch, 1977, pp 56-57). Thus, given this evidence, and the notion that “[organisms] must prefer those environments in which it is likely to thrive” (Kaplan & Kaplan, 1982, p 147), it is reasonable to expect that greener natural settings, preferred by children, would also have a beneficial effect on their sleep.

Chapter 3 Methods

This chapter will describe the various methods utilized for this research project and will explain key concepts. The chapter is divided into two main portions. The first portion entitled *Data Techniques and Collection,* will describe how the STEAM project was conducted, the sample participants, the various data collection tools used, and will explain key variables (independent and dependent). The second portion entitled *Geographic Information System Analysis* will provide a description and explanation of the two GIS approaches used as an aid for this study: neighbourhood level analysis (to measure environmental opportunities) and individual level analysis (to measure individual daily environmental exposures). This section will detail the GIS tools and techniques applied for the application of the two approaches and the various statistical analyses.

3.1 Data Techniques and Collection

3.1.1 Research Methods: STEAM Project

This thesis derives its data from a recently completed Spatial Temporal Environment and Activity Monitoring (STEAM) research project. The data sources collected in this larger project helped define the core methods used for this thesis. The STEAM project's primary objectives are to explore and assess how the physical environment (consisting of built and natural features) influences children's everyday physical activity patterns and food habits. The STEAM project began in 2010 and concluded in the spring of 2014, with the first year representing the pilot study (STEAM 1) and each subsequent year hosting a new session of the project (STEAM 2.1, 2.2, and 2.3). The larger project collected data from 946 children from 30 schools across

Southwestern Ontario (SWO). This thesis utilizes the data collected from each spring session (STEAM 1 and 2) from elementary schools located within the City of London (n=22). A map of the school locations and land use classifications are displayed in Figure 3.

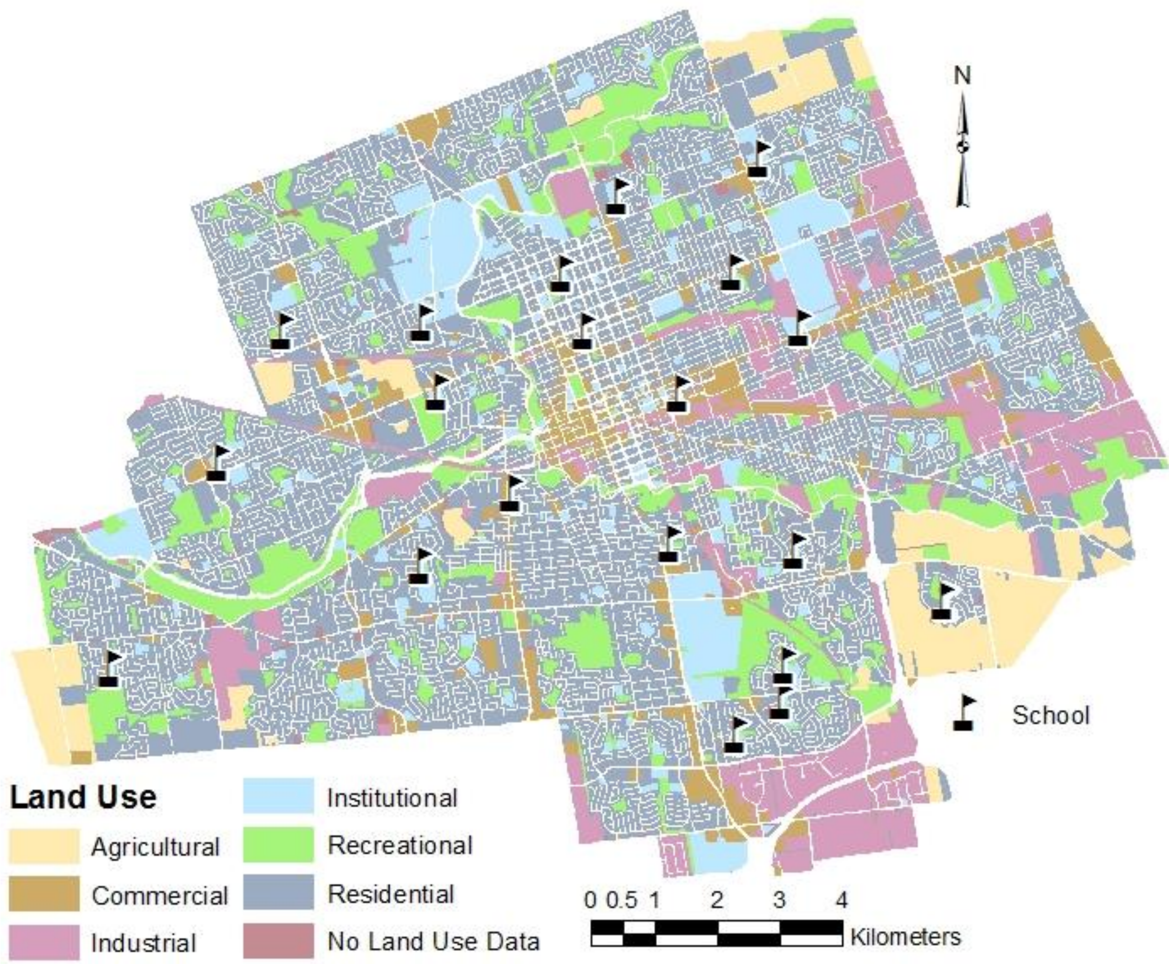

Figure 3: Location of study schools in the context of land use classification

(City of London, 2011)

3.1.2 Sample Participants

Demographic and spatial data on a sample of students in grades 4-8 (aged 9-14 years) from London, Ontario was collected from 2010-2013 (n=614), with the majority of students (94.6%) in grades 5-7 (aged 10-12 years). This age group is ideal as the participants are able to self-report their own activity and sleep patterns and do not have to rely on parent-reports (Fredriksen et al., 2004) which can lead to certain biases, including exaggerated sleep times (Sadeh, 1994). Additionally, this is a critical age when children develop independent mobility and a sense of their own environment (Rissotto & Tonucci, 2002). The spatial area of London, Ontario, is apt because it provides a range of built environment and socioeconomic diversity within the study population. In addition, working at a community level provides the opportunity to disseminate relevant contextual results to local planners and policy makers.

Recruitment Procedures. Recruitment of schools and students was completed in multiple stages. First, ethics for the STEAM project was granted by the Non-Medical Ethics Board of Western University (see Appendix A). Additional ethics approval was then obtained from the various school boards (Thames Valley District School Board (English Public), London District Catholic School Board (English Catholic), Conseil Scolaire Viamonde (French Public), and Providence Conseil Scolaire Catholique (French Catholic)). Principals of selected schools were then contacted and given letters of information regarding the STEAM project. Upon approval of participation from the principal, STEAM researchers recruited student participants by conducting a class presentation. Students were sent home with a letter of information for the parents and / or guardian, a consent form to be signed by the parent and / or guardian and parent and /

or guardian survey to complete. Students were eligible to take part in the project once consent was given by parent/guardian. On the starting day of STEAM, students with returned parental consent forms signed a child assent form confirming their continued interest in participating in the project.

3.1.3 Data Collection: STEAM Tools

The STEAM research project consists of two phases of data collection for each year. This includes seven consecutive observation days (five weekdays and two weekend days) in the spring and a follow up session in the fall using the same methods and students. Only the data sources used for this thesis will be described.

To ensure high participation rates plus accurate and consistent use of equipment, researchers of the STEAM project visited each school daily. Although resource and time intensive, this method ensured compliancy rates that would not have been possible if equipment were simply dropped off and collected a week later as is done in similar studies (Cooper et al., 2010). Regular and routine communication and interaction with the students allowed for trouble shooting and clarifying of issues that may occur with any aspect of the project.

On the first day (set-up day) participants were assigned equipment and were instructed on procedures for completing diary entries and use of GPS units (shutting them down at night to charge and turning them back on in the morning). Height and weight of each participant were measured using a digital scale and tape measure with standard methods (indoor clothing remained on, shoes were removed). For the following data collection days, researchers checked diary entries with students to ensure completeness and confirm participants were properly wearing GPS units. If diary entries were incomplete, STEAM researchers would go through the diary with the student and help them complete any unfilled pages so the richest possible data was still collected. On the final day, students returned equipment and completed the survey.

Global Positioning System Data Points

Children were equipped with a portable Global Positioning System (GPS) (Visiontac VGPS-900) for seven consecutive days. The GPS units were attached to a collapsible lanyard which students wore around their neck over their clothing. The GPS allows for the outdoor location of the participant to be objectively measured with high accuracy and frequency (Almanza et al., 2012; Cooper et al., 2010). These locations are time stamped and recorded by waypoint in one second epochs. The students were instructed to wear the GPS equipment during waking hours, except when bathing or swimming. As per Cooper et al's suggestion, the use of GPS devices can provide a "novel method to measure time outdoors in free-living young people" (2010, pg. 6). The GPS data points are specifically used in this study to determine where, when, and for what length of time participants utilized green space areas and other features of their surrounding environment. The use of GPS units to objectively determine how individuals interact with their surrounding physical environment are increasingly being used and is considered the gold standard for this type of data collection (Almanza et al., 2012; Cooper et al., 2010). Alternative methods, such as estimations by parental proxy or participant self-report have been used in previous studies; these methods, however, are subject to biases related to recall of location or misclassification (Burdette et al., 2004; Collins et al., 2012; Elgethun et al., 2007; Lachowycz, 2012; Rainham et al., 2008).

Daily Activity Diary

Participants were asked to fill out a daily activity diary which provides important contextual information that accompanies the spatial data. GPS data points are able to determine the location of activity; these points are however, unable to determine the exact nature of activity. This is why the activity diaries are essential for capturing accurate data. Insights into the activities children engaged in throughout the day are among the many insights gleaned through this innovative methodology. During school days students filled out information about their day including activities before school, travel to school, recess and lunch activities, and after school activities. Activity diaries during the weekend were broken up by different time blocks asking students to fill out what they did before lunch, after lunch, and after dinner and where they spent the majority of their time (i.e. indoors, outdoors, at a friend's house).

Survey Data

Youth Survey: The "Healthy Neighbourhoods Survey for Youth" is a 14-item (172 question) survey completed by participants on the final day (day seven) of each session of study. The survey hosted a wide range of questions targeting various categories including: demographic data, physical and recreational activity patterns, mode of travel to and from school, barriers to active travel to and from school, eating habits, neighbourhood characteristics, and household rules and safety concerns. A researcher from the STEAM project distributed the survey to students with instructions on how to properly complete it, the survey took approximately 30 minutes to complete.

Parent Survey: The "Healthy Neighbourhoods Survey for Parents" is a supplementary survey distributed to the parents of participants. This survey is a 12-item (148 question) optional survey completed during the parental consent period. This survey posed complimentary questions to the youth survey with additional questions including: household income, parental education, and parental work status.

3.1.4 Measures

This section is intended to explain and provide clarification of the variables used (dependent and independent) and how they were derived for the purpose of this thesis.

3.1.4.1 Dependent Variable

The primary outcome measure for this thesis is sleep duration which is derived from questions in the activity diaries. Each day, students answered the following questions: "I woke up today at" and "I went to bed at __ o'clock". The difference between the bed time and subsequent wake time indicates the duration of sleep. Self-reported measurements of children's sleep duration is consistent with more objective measures of sleep, such as actigraphy (Werner et al., 2008; Wolfson et al., 2002), making this method a valid way of determining this measure. During the explanation period, STEAM researchers instructed students to record the time they fell asleep, as opposed to their scheduled bed time, as a way of trying to mitigate the differences in accounting for time it took students to fall asleep. Students were included if they had a minimum of two weekday and one weekend day of sleep duration recorded. Extreme outliers in sleep durations (less than 3 hours and greater than 15 hours) were removed as these were considered errors in reporting.

3.1.4.2 Independent Variables

This section is divided into two sections, individual and environmental measures, in order to define and explain key terms of the independent variables used within this thesis. For further explanation on particular variables used see Appendix B.

Individual Measures:

The individual measures are reported in Table 1, highlighting the STEAM tool where they were derived from and what questions were asked to determine them.

Table 1: Individual level measures defined and the tool derived from

Variable	Tool Derived From	Question Asked / Computation
Sex	Healthy Neighbourhoods Survey for Youth	I am female or male
Age	Individually asked birthday by STEAM researcher	Asked birthday directly when measuring BMI
Grade	Healthy Neighbourhoods Survey for Parents **OR** Daily Activity Diary Cover Page	What grade is your child currently in? **OR** Grade: _______
Ethnicity	Healthy Neighbourhoods Survey for Youth	What is your primary race / ethnic background? Ethnicity was then divided into "non-visible minority"(White) and "visible minority" (Chinese, Black, Latin American, Arab, Japanese, Aboriginal, South Asian, Filipino, West Asian, or Korean) (Lumeng et al., 2007) categories as each one category only represented a very small sample size.
Income	Healthy Neighbourhoods Survey for Parents	Please indicate the total income from all sources that you and other members of your household received in the last year (Jan-Dec) before taxes. Household income was then divided into five categories: <$20,000-39,999, $40,000-79,000, $80,000-129,000, +$130,000, and no-response
BMI z-score	Objectively measured height and weight by STEAM researcher	Was calculated from measured height and weight and adjusted for age (by month) and sex (CDC, 2014). The z-score is the number of standard deviation units that the child's BMI

		deviates from the mean (Bell et al., 2008).
Total Quality of Life	Healthy Neighbourhoods Survey for Youth	Measured using the Pediatric Quality of Life Inventory TM (PedsQL) (Vami et al., 1999). Four primary scales were used to calculate: physical (8 items), emotional (5 items), social (5 items), and school functions (4 items). Scores ranged from 0-100, with higher scores equating to better self-reported quality of life
Number of people living in house	Healthy Neighbourhoods Survey for Youth	How many people live (including yourself AND other children) in your primary household? zero, 1, 2, 3, 4, or 5+
Number of siblings living in house	Healthy Neighbourhoods Survey for Youth	How many other children (NOT including yourself) live in your primary household? zero, 1, 2, 3, 4, or 5+
Total amount of screen time per day	Healthy Neighbourhoods Survey for Youth	Calculated from a matrix. Five categories (watching T.V / videos, playing video games or computer games, playing hand-held game players, using the internet or emailing, and talking or texting on a cellphone) were asked at various lengths of time used / watched per day. From these groups a weighted time per activity was calculated and added together for all activities to get a total average screen time spent per day
T.V. in bedroom	Healthy Neighbourhoods Survey for Youth	Do you have a TV in your bedroom? Yes, No
Commute time to school	GPS Data Tracks	GPS tracks of the route to school were examined. The most representative and complete route was chosen as the typical route taken by that student. Since the GPS units time stamp, a length of time in seconds was computed (then multiplied by 60 to determine the number of minutes)
Active vs. Inactive Commuter	Healthy Neighbourhoods Survey for Youth	Number of days per week you **usually** travel **to / from** school by: walking, bicycle/scooter, skateboard/rollerblade, car, school bus or city bus. Students circled a number between 0-5 totalling 5. The mode with the highest value was deemed as active (walking, bicycling/scooter or skateboard/rollerblade) or inactive

		(car, school bus or city bus).
School Start Time	Provided by School	The amount of minutes from 12:00am the school start time was, thus the greater the minutes the later the school start time
Average PA (from accelerometer)	Accelerometer Data	For each valid day of the study period, the total minutes spent in each activity intensity category were totaled under each time-block category. This provides a measure for total amount of time (in minutes) the child spent in each activity intensity category for every time-block of each day. To obtain an average time spent of activity intensity by time-block over the course of the study, these values were then averaged out over the amount of valid days observed in the study frame
Sedentary Activity	Accelerometer Data	Activity Counts <100
Light Activity	Accelerometer Data	Activity Counts 100 - <1500
Moderate Activity	Accelerometer Data	Activity Counts 1500 - <6500
Vigorous Activity	Accelerometer Data	Activity Counts ≥6500
Moderate to Vigorous Activity	Accelerometer Data	Combined activity counts of moderate and vigorous (1500- ≥ 6500)

Neighbourhood Level Sociodemographic Measures

Neighbourhood level sociodemographic measures were collected from census data from Statistics Canada (2006). This data was collected at the Dissemination Area (DA) level as it is the smallest aggregated geographic unit of dissemination produced by Statistics Canada (Healy & Gilliland, 2012). Data at the DA level are commonly used in health studies. The variables used from the census data are: total population, average number of children per household, unemployment rate, percentage of low income households after tax, percentage of lone parent households, percentage of immigrants, percentage of new immigrants, percentage of individuals without high school diploma, percentage of visible minority, percentage of people aged 0-19, percentage of home ownership rates, and median family income. A composite index of socio-economic distress was calculated from four census data variables (percentage of individuals without high school diploma, lone parenthood, unemployment, and low income) to account for multiple indicators of distress (Larson & Gilliland, 2008). These variables are further defined in Appendix B.

Environmental Measures

Green space. The primary independent variable of interest, green space, was derived from the following environmental variables: Normalized Difference Vegetation Index (NDVI), tree count, and park space. NDVI is the most commonly used vegetation index to estimate greenness (Grigsby-Toussaint, Chi & Fiese, 2011) and has been proven as an effective means of capturing neighbourhood greenness for epidemiologic purposes (Rhew et al., 2011). NDVI can be utilized to obtain a quantitative measure of the vegetation density and distribution. NDVI works on the basis that chlorophyll, found in plants, strongly absorbs red light and reflects Near Infrared Light (NIR), which is defined by Lillesand, Kiefer & Chipman (2004) in the following equation:

$$\text{NDVI} = \frac{NIR - RED}{NIR + RED}$$

The outcome is a bounded ratio with a value between -1 and +1. Values greater than 0.1 indicate increasing degrees in the greenness and intensity of vegetation. Surfaces containing vegetation will typically have NDVI values which range from 0.1 (typical of more desert areas) up to values of 0.8 (characteristic of dense tropical forests) (Grigsby-Toussaint, Chi & Fiese, 2011; Lillesand, Kiefer & Chipman, 2004). Values that lie between 0 and 0.1 are typical of bare soil or rocks and values less than 0 indicate surfaces such as water, snow or ice (Lillesand, Kiefer & Chipman, 2004). Values of NDVI less than 0.0 were reassigned to a value of 0.0. This is because a negative NDVI value is indicative of water, snow or ice (Lillesand, Kiefer & Chipman, 2004) and is thus not a representation of green. An NDVI value of 0.0 is indicative of rock or bare soil (Lillesand, Kiefer & Chipman, 2004); which is also not a representation of green so will not bias the results in any way. For the City of London, NDVI was obtained through aerial photography at 30 cm resolutions from August 2008. Due to timing of data collection and the time the air photo was taken, an assumption that no change in the mean NDVI is made. NDVI was scaled by a factor of 10, to simplify interpretation. so that a one-unit increase in NDVI (i.e. 0.01) would correspond to land use changes that are observable in an urban setting (for example from parking lots with little green vegetation to school yards with moderate green vegetation) (Bell et al., 2008; Grigsby-Toussaint, Chi & Fiese, 2011). Figure 4 represent a snap shot of the City of London with the respective NDVI values.

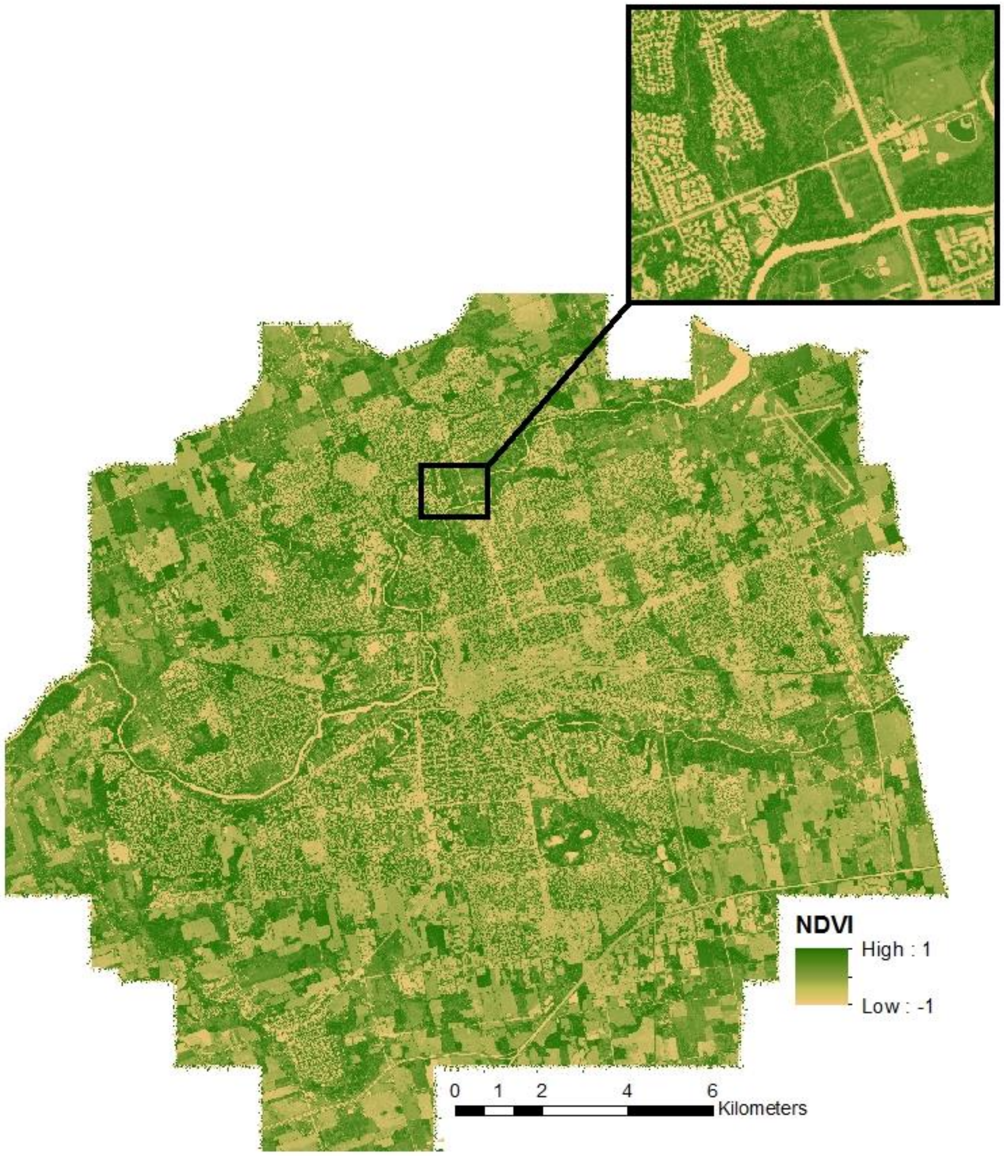

Figure 4: NDVI readings for a section of the City of London (City of London, 2008)

Tree count was calculated from the City of London (2011) data source to determine the number of city owned trees within a particular area (i.e. neighbourhood). This does not include private trees, but, those would be captured through NDVI readings. The amount of park space (in 1000 m^2) was calculated from the City of London (2011) data source which includes open space fields and city-owned public park space. The methods used to calculate these variables are described in forthcoming sections of this chapter.

Other Environmental Variables

Land use mix was used to determine the amount (in 1000 m^2) of each land use category (commercial, industrial, institutional, residential, recreational, agricultural, and no land use) for a given area, a definition of each land use is provided in Appendix B. The minimum, maximum, and average daily traffic volumes were determined from the City of London (2005). Traffic volume can be used to gain insights to the level of noise pollution (Bluhm et al., 2004) in order to explore if traffic volume has an impact on the outcome measure. The number of road intersections (measured by road connectivity) was generated to examine the intensity of urban form within the surrounding area (i.e. a greater number of intersections would be more representative of a city center). The amount of building space, roads, sidewalks, bike paths, multi-use pathways, and water bodies were all examined to determine a wide-ranged indication of the surrounding environment and an indication of urban form intensity and was provided by the Planning Division of the City of London (2011).

3.2 Geographic Information Systems Analysis

3.2.1 Neighbourhood Level Analysis

To answer the research questions, two different GIS approaches were used, one at the neighbourhood level (described in this section) and one at a more in-depth level of analysis exploring individual daily exposure using a hexagonal grid surface (explained in section 3.2.2). The purpose of neighbourhood level analysis is to use GIS opportunity measures to determine the impact that children's surrounding physical environment has on their average duration of sleep (including all recorded weekday and weekend durations), to answer the first two research questions. Previous studies indicate that a child's surrounding neighbourhood environment creates barriers or opportunities within many aspects of their lives (Gilliland et al., 2006; Gordon-Larsen et al., 2006). The influences on access to recreational spaces for physical activity are amongst the most commonly reported (Gilliland et al., 2006; Moore et al., 2010). Similarly, connections have been linked with opportunity to recreational facilities and the likelihood of being overweight or obese (Gordon-Larsen et al., 2006). Greater access to nearby nature has been found to bring positive benefits, such as heightened attention levels and emotional self-regulation ability (Faber Taylor et al., 2002). Less frequently reported are the environmental factors which influence children's sleep duration. Children's surrounding neighbourhood may impact their sleep directly, for example by noise pollution, from traffic which has been reported to negatively impact children's sleep duration (Linares et al., 2005) or indirectly through mediators. Potential mediators include behavioural elements, such as physical activity levels, or psychological elements, such as reduced mental well-being (Pabayo et al., 2014).

Neighbourhood. Each participant's home location was geocoded to generate an accurate description of the surrounding neighbourhood characteristics. Neighbourhoods were defined in the form of Euclidean (radial) buffers around each student's home, which has been previously used for exploring child accessibility (Larsen et al., 2009). Euclidean buffers were used (instead of network buffers for example) as green space is the main independent variable of inquiry. Network buffers are based on the level of street connectivity around the area (Bell et al., 2002), and therefore would eliminate green space areas due to their nature. For example the network buffer would not go through a school yard or a park, which are fundamental for this study. Additionally, children are more "free range" than adults, so Euclidean buffers are more suitable. Four buffer sizes, to offer sensitivity analysis, were generated using GIS software (ArcGIS v10.1) at 500m, 800m, 1000m and 1600m, shown in Figure 5. These buffer sizes were chosen based on their use in previous studies exploring children's neighbourhood environments (Kerr et al., 2006; Larsen et al., 2009; McDonald, 2007) and to represent a reasonable walking distance from residence. Within each of these buffers, the various individual and environmental measures were calculated and attached to the buffer using functions in ArcGIS 10.1 (ESRI).

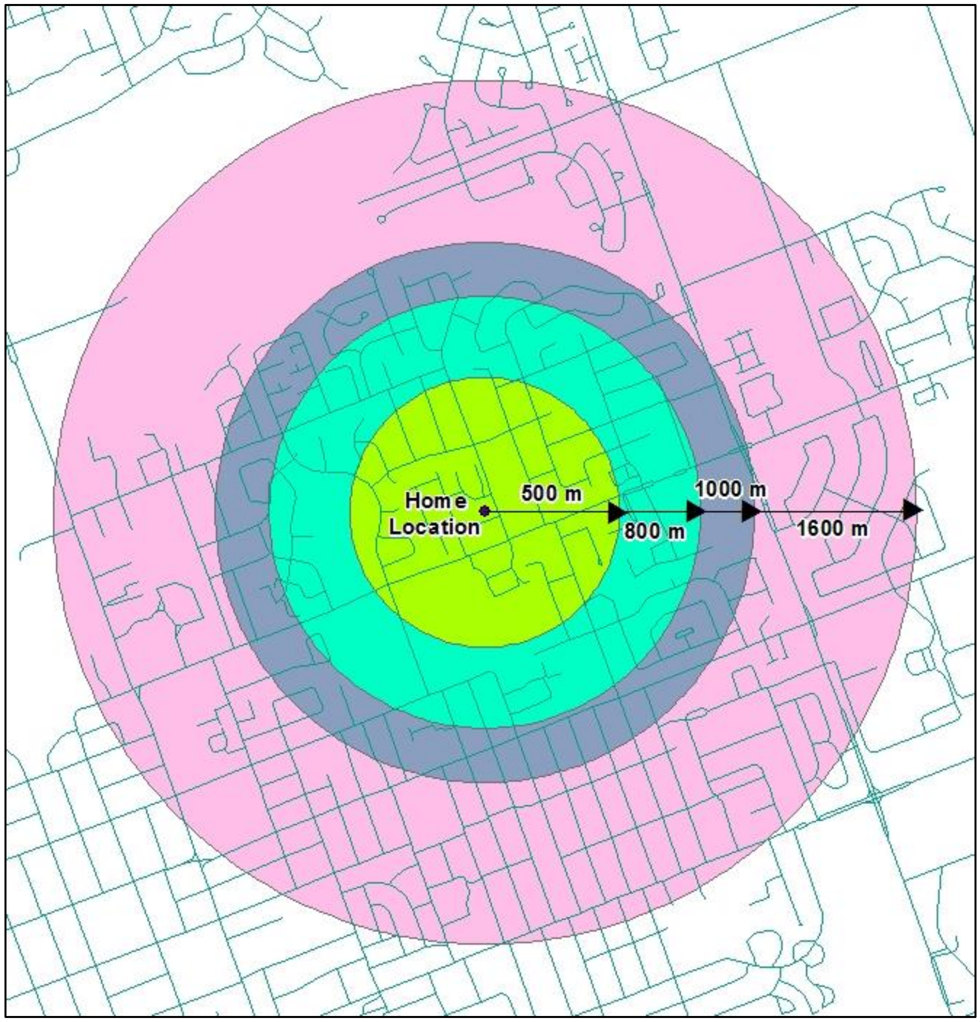

Figure 5: Euclidean buffers around a hypothetical child's home at 500m, 800m, 1000m, and 1600m

3.2.1.1 Quantifying Environmental Variables for Buffer

Using the GIS software program ArcGIS v10.1, the four buffers around each participant's home location were created using the Buffer tool. To calculate the amount or average of each environmental variable within the buffers, va0rious ArcGIS tools were used, which are displayed in Table 2.

Table 2: Classification of GIS Tool Applied

Environmental Variable	ArcGIS Tool Applied
Average NDVI Reading	Zonal Statistics
Tree Density Count	Spatial Join
Road Connectivity (# of intersections)	Spatial Join
Traffic Volume (min, max and average)	Spatial Join
Neighbourhood level sociodemographic variables (DAs)	Spatial Join
Park Space (1000 m^2)	Intersect Analysis
Land Use Mix (1000 m^2)	Intersect Analysis
Building Space (m^2)	Intersect Analysis
Road Space (m^2)	Intersect Analysis
Sidewalk Space (m^2)	Intersect Analysis
Multi-use Pathway Space (m^2)	Intersect Analysis
Bike Path Space (m^2)	Intersect Analysis
Water Body Space (m^2)	Intersect Analysis

Each variable was calculated based on the corresponding buffer size. For example, the amount of park space would vary depending on the buffer size: typically larger buffer sizes would yield more park space. For the census data, the DA which the child's home location fell within was used for calculating neighbourhood level sociodemographic data. After completion of each generated value, a table join was performed to include all necessary variables within one comprehensive table.

3.2.1.2 Statistical Inference

The final table was imported into a statistical and data analysis program (STATA v13.1). The Shapiro-Wilk test of normality was run to test the null hypothesis that the sample came from a normally distributed population (Rogerson, 2010). Variables were considered normally distributed if the p value was greater than 0.05. The appropriate bivariate correlations were run to assess the strength of the association between the dependent variable (average sleep duration) and potential independent variables. A series of hierarchical multiple linear regression models, adapted from a strategy developed in previous studies (Bjorvatn et al., 2007; Paavonen et al., 2009), and following the Socio-Ecological model of Health Behaviour, were run at each buffer size. Multiple linear regressions are used as a more complete process to explore the relationship between the dependent variable and a set of independent, explanatory variables (Rogerson, 2010). There are four stages to the hierarchical regression with each stage building successive linear regression models by adding more predictor variables. Model 1 includes individual level and socioeconomic variables. Model 2 adds additional individual and behavioural characteristics while controlling for the previous individual level and socioeconomic variables. Model 3 adds in neighbourhood level sociodemographic variables while controlling for individual and socioeconomic variables, and individual and behavioural variables. Model 4 adds in variables about the surrounding neighbourhood physical environment while controlling for the individual and socioeconomic characteristics, individual and behavioural variables, and neighbourhood level sociodemographic variables. A correlation was run to test the relationships between all independent variables to check for multicollinearity. Correlations higher than 0.8 were deemed too similar, in which case only one would be used within the regression models.

The Variance Inflation Factor (VIF) was checked after the completion of each regression model as another indication of multicollinearity (O'Brien, 2007). A VIF value greater than 10 was considered a cause for concern (Hair et al., 1998; Kutner et al., 2004; O'Brien, 2007). After completion of each multiple regression, testing for the four assumptions of multiple linear regressions was performed. These assumptions are: there should be a linear relationship between the x and y variables, the residuals should be normally distributed, there should be constant variability of the residuals, and there should be independence of the residuals (Rogerson, 2010).

3.2.2 Individual Exposure Analysis

Neighbourhood level analysis provides a method to examine the opportunity that children have within their surrounding neighbourhood. Opportunity, however, is not an accurate indication of what children are truly exposed to on a daily basis; instead it examines what they *could* be exposed to. To take this a step further, daily individual level exposure will be explored to answer the remaining research questions. This provides a deeper analysis of how children's transactions with their environment offer potential constraints and opportunities for health promoting or harmful behaviours. This analysis will explore participants' daily exposure to green space and other environmental features in conjunction with their respective daily sleep duration. To concretely determine daily time spent exposed to various environmental features, a hexagonal grid surface was developed in ArcGIS v 10.1. Hexagons were used over their counterpart (rectangles or squares) as they offer a "simpler and more symmetric nearest neighbour, which avoids the ambiguities of the rectangular grid" (Birch, Oom & Beecham, 2007). This is an important consideration when using spatial patterns to avoid spatial autocorrection (Jurasinski & Beierkuhnlein, 2006). Hexagons have a smaller parameter than a square which reduces bias of edge effect (Birch, Oom & Beecham, 2007).

Exposure Space. The GPS tracks of each student were superimposed onto the hexagon grid surface. Since the GPS points were recorded in one second epochs, a count of points provides the time (in seconds) spent within each hexagon. Attached to each hexagon are the environmental attributes. The calculations of the variables attached are explained in the following section (3.2.2.1). The amount of time spent in each hexagon will allow for the calculation of exposure to green space and other various environments. An example of the hexagon surface and the attached environmental variables is shown in Figure 6. Since the schools provided their daily time tables, combined with the GPS time stamps, time blocks were derived per day. This enabled the determination for “out of school time” versus “in school time”. Any time block which was deemed “in school” was removed for two reasons: 1) the students were inside a building so therefore there was an increased likelihood that GPS units would produce more erroneous data points, and 2) “in school” time is a large time block within a student’s day which the majority is spent indoors. It should be noted that “in school” time does not include morning, lunch, or afternoon recess time. Since exposure to green space is the primary independent variable, exploring the times where students at least have the option to be outside in green space is more applicable. Additionally, for inclusion, students were required to have at least two hours of GPS data points (for that day) outside of school hours. This ensured that a sufficient amount of time per day was captured for each student. No standardized number of hours has been established within the literature to date (Cooper et al., 2010); based on decisions of project team members, two hours was deemed appropriate for this data set. Students were removed if they had less than two hours of GPS data points.

Variable	Value
Shape Area	259.808m^2
NDVI	0.19
Tree Count	0
Park Area	259.808 m^2
Residential Area	0 m^2
Agricultural Area	0 m^2
Recreational Area	259.808 m^2
Commercial Area	0 m^2
Institutional Area	0 m^2
Industrial Area	0 m^2
Building Area	0 m^2
Road Area	0 m^2
Bike Length	0 m^2
Sidewalk Length	0 m^2
Multi-Use Paths	0 m^2
Water Area	0 m^2
Max Traffic Volume	0
Road Intersections	0

Figure 6: Hexagon surface superimposed onto an orthophoto of the City of London (2008) with the corresponding attached environmental variables

3.2.2.1 Quantifying Environmental Variables in Hexagon Surface

Using ArcGIS v10.1, environmental variables were attached to each hexagon using the same tools as applied to the buffers (refer to Table 2). Exposure to environmental variables was calculated as time spent within each hexagon was determined from the GPS time stamps. Because this research is exploratory in nature, when examining the green space variables, a variety of ways were generated to determine the respective influence on the outcome measure. An explanation of the calculations of each attached environmental variable is as follows:

NDVI: Three different methods were used to calculate the NDVI level exposed to on a daily basis: 1) weighted-mean measure of exposure, 2) the amount of time spent in a green area, and 3) the amount of time spent in categories of increasing greenness.

To generate the weighted-mean measure of exposure to green, time spent (number of seconds) within each hexagon was calculated. This value was then multiplied by the corresponding NDVI index of the hexagon to get a weighted measure of green. To derive the average-mean exposure index, the total number of weighted NDVI exposure was then divided by the total amount of recorded GPS time per day. Below provides an example of how this variable was generated.

Student	Day	HID	Seconds Spent	NDVI	Weighted NDVI	Weighted-mean NDVI
1005	1	1	60	0.15	9	
1005	1	2	2	0.05	0.1	
		Total	62		9.1	**0.147**

To generate the second measure of NDVI (the amount of time spent in a green area), a binary variable was created. Hexagons with a mean NDVI value greater than or equal to 0.15 was considered as green areas for this research. Thus the time spent in a hexagon where NDVI values were greater than or equal to 0.15 were assigned a 1 while the time spent in hexagons with an NDVI value of lower than 0.15 were assigned a value of 0.

To generate the final measure of NDVI exposure, a categorical variable was produced. Derived from previous literature, NDVI may be classified into three categories consisting of low (0.0-0.15), medium (0.151-0.3), and high (0.31-1) values (Lillesand, Kiefer & Chipman, 2004). However, based on the data collected from this study, children were found to spend a very small amount of time within medium or high NDVI categories. Therefore, the three categories were low (0.0-0.002), medium (0.0021-0.1), and high (0.11-1.0) based off the data. The total amount of seconds spent per day within each of the categories was determined.

Tree Count: Similar to NDVI, the amount of tree exposure was also generated in three manners to test the respective influence on the outcome with statistical analysis. The three variables generated were: 1) weighted-mean measure of exposure to trees, 2) the amount of time spent in a hexagon with trees, and 3) the amount of time spent in categories of increasing tree density.

To generate the weighted measure of exposure to number of trees, the number of trees within each hexagon was calculated. This value was then multiplied by the corresponding number of seconds spent within the hexagon. To generate the weighted measure of tree exposure, the total number of weighted tree exposure was divided by the total amount of recorded GPS time per day.

To generate the second measure of exposure to trees (the amount of time spent in an area with trees), a binary variable was created. Hexagons with a tree count greater than or equal to 1 were considered as "green" for this research. Thus the time spent in a hexagon where the tree count was greater than or equal to 1 were assigned a value of 1 while the time spent in hexagons with a tree count of 0 was assigned a value of 0.

To generate the final measure of exposure to trees, a categorical variable was derived. Three categories were determined based off the data to represent low (0-2 trees), medium (3-5 trees), and high (6+ trees) tree exposure. The total amount of seconds spent within each category per day was determined.

Land use mix & Park space: For the various land use types (i.e., commercial, industrial, institutional, agricultural, recreational, and residential) and park space, a binary variable was created. If a variable (i.e., a land use type or park space) was present within the hexagon a value of 1 was assigned. If the variable was not present within the hexagon, a value of 0 was given. The number of seconds spent within each hexagon exposed to the particular variables provides the indication of exposure to different land use types and park space. The amount of land use or park space within the hexagon is not considered because each hexagon is small in area (259.808 m^2); therefore the amount of each variable within the hexagon is trivial. For this examination, the presence of the specific land use or park space is sufficient.

The land use found in the buffers as "no land use" was redistributed for the purpose of measuring exposure. This is because this variable accounts for other environmental features (roads and water bodies) which will be accounted for separately using the appropriate feature polygon. Therefore, 'no land use' is not an accurate representation of what is in the hexagon and what the participant will be exposed to while present in that hexagon. The value of no land use for each hexagon will be redistributed to the highest other land use category within the hexagon to ensure a true measure of the participants' exposure of that particular land use. If no other land use category is present, a spatial weights matrix will be run in ArcGIS, so that the no land use will be assigned the land use of the nearest neighbour hexagon.

Road Connectivity: Similar to NDVI, a weighted measure of exposure to road intersections was calculated, to get an average number of intersections each student is exposed to daily. First, the number of seconds spent within each hexagon was calculated.

This value was then multiplied by the corresponding number of road intersections within each hexagon to get a weighted measure of road intersections. To derive the average-mean exposure, the total number of weighted road intersections was then divided by the total amount of recorded GPS time per day.

Traffic Volume: The minimum, maximum, and average daily traffic volume on streets within each hexagon was calculated. This will provide information regarding the type of street the child is exposed to and for what length of time. For instance a higher maximum traffic volume is indicative of a larger, busier road. Traffic volumes greater than 10,000 vehicles/day are considered busier streets for this study. A binary variable was created, the amount of seconds spent per day on roads exposed to traffic volumes of 10,000 and greater was assigned a value of 1, while the seconds spent exposed to traffic volumes less than 10,000 were assigned a value of 0.

Road Length, Bike Path Length, Sidewalks, Multi-use paths & Buildings: To calculate these environmental features a binary variable was created for each variable to indicate if the feature is present within the hexagon or not. If the feature was present within a hexagon a value of 1 was assigned, if the feature was not present within the hexagon a value of 0 was assigned. From this, the total amount of seconds spent per day was calculated to determine the amount of exposure per day to each of these features.

Census Data: The census data will be treated as neighbourhood level data for the purpose of individual level exposure. Thus, the census data that is representative at the child's home location will be used. The DA which the child's home location fell within was chosen to represent that participant's neighbourhood characteristics. This represents neighbourhood level sociodemographic information which could have an influence on the child's daily sleep duration.

Urban/Suburban/Rural: Similar to the census data, a child's home location (categorized as urban, suburban or rural) will be treated as neighbourhood level data.

3.2.2.2 Statistical Inference

The final table was again, imported into a statistical and data analysis program (STATA v13.1). Statistical investigation will be similar to those completed for the neighbourhood level analysis. The Shapiro-Wilk test of normality was run on all variables to test if the variables come from a normally distributed sample. The appropriate bivariate correlations were run between the dependent variable (daily sleep duration) and the independent variables to determine which are significantly associated.

Similar to the neighbourhood level analysis, a series of hierarchical multiple linear regression models will be run to explore the relationship between student's daily times exposed to various environmental features and their daily sleep durations. Four stages to the hierarchical regression will be completed, with each stage adding additional predictor variables. Model 1 will add individual level and socioeconomic characteristics, model 2 will add additional individual and behavioural characteristics, model 3 will add in a child's neighbourhood sociodemographic characteristics, and model 4 will add in environmental variables that the child is exposed to on a daily basis. A correlation was run to test the relationships between all independent variables to check for multicollinearity. Correlations higher than 0.8 were deemed too similar, in which case only one would be used within the regression models. Additionally, the VIF was tested after the regression was complete as a second check for multicollinearity. Testing for the four assumptions of multiple linear regressions were also performed to determine if the model, and the variables within, met each assumption.

Chapter 4 Neighbourhood Level Results: Examining the Impact of Individual Level Factors and Environmental Opportunities on Children's Sleep Duration

This chapter presents the findings from the neighbourhood level analysis. The purpose of the neighbourhood level analysis was to use the commonly used "buffer" approach of estimating environmental opportunities/accessibility to gain insight into whether opportunity to green spaces or other environmental features impacts children's sleep duration. This approach seeks to address the overarching research question: to what extent do green spaces and other built environmental features impact children's sleep duration? This approach will also address the first two supplementary research questions: 1) does greater availability of green space in an individual's neighbourhood have an impact on the duration of sleep? And 2) what physical environmental factors (including natural and built) surrounding the child's home neighbourhood have an influence on children's sleep duration? The results were generated through analyses done with ArcGIS 10.1 and Stata 13.0, as describe in the previous chapter.

4.1 Participants

Students who participated in the spring 2010, 2011, 2012 and 2013 seasons of the STEAM project were eligible for inclusion (n=614). Of those eligible, 525 (85.5%) were included in the study. The 89 ineligible students either had missing GPS data points (which prevented determination of their home address) (n=21), lived outside of the City of London's boundary (n=42), or did not have adequate recorded sleep data (n=26). Table 3 displays characteristics of the sample.

Table 3: Sample Characteristics

Sample Characteristics (n=525)	Number (n, %)
Age, n (%)	
9	9 (1.71)
10	82 (15.62)
11	232 (44.19)
12	154 (29.33)
13	45 (8.57)
14	3 (0.57)
Sex, n (%)	
Male	209 (39.81)
Female	316 (60.19)
Ethnicity, n (%)	
Non-Visible Minority	268 (51.05)
Visible Minority	102 (19.43)
Prefer not to say	155 (29.52)
Parental Income, n (%)	
<$20,000 – 39,000	44 (8.38)
$40,000 – 79,000	62 (11.81)
$80,000 – 129,000	68 (12.95)
+$130, 000	63 (12)
Prefer not to say	288 (54.86)
BMI Z-Score, µ	0.14
Screen Time / day (hours), n (%)	
<2	69 (13.14)
2.1 – 4	78 (14.86)
4.1 – 6	77 (14.67)
6.1 +	73 (13.9)
Prefer not to say	228 (43.43)
Commute time to school, µ minutes	14.82
Commute Mode, n (%)	
Active	190 (36.15)
Inactive	335 (63.85)
School Start Time, µ	8:57 am
Neighbourhood Classification, n (%)	
Urban	89 (16.95)
Suburban	429 (81.71)
Rural	7 (1.33)

The majority of the students were of non-visible minority status (51%). 82% of the student's reside in suburban neighbourhoods with the remaining students residing in urban (17%) and rural (2%) neighbourhoods. The average commute time to school was

14.8 minutes, with 64% of the sample using inactive modes of transportation. The majority of participants commuted by school bus (38%) followed by walking (34%) and private automobile (26%).

The average sleep duration was 580.47 minutes (9.67 hours), which is consistent with the literature for children of this age group (Carskadon et al., 1980; Spilsbury et al., 2004). 38% of students slept less than the average of 9.67 hours a night. The average sleep duration on a school day was 579 minutes (9.65 hours), while the average sleep duration on the weekend was 584.4 minutes (9.74 hours), averaging to an additional 5.4 minutes of sleep on the weekend. Children who are overweight or obese slept less than expected, while non-overweight children slept more than expected (p=0.04). Children classified as overweight or obese slept an average of 5.2 fewer minutes per night than non-overweight children. A breakdown of the average sleep duration by age is presented in Table 4.

Table 4: Average sleep duration and recommended sleep duration breakdown by age

Age	Average Sleep Duration	Recommended Sleep Duration	% Obtaining Recommended Duration
9	9.99 hours	10 hours	56%
10	9.93 hours	10 hours	54%
11	9.71 hours	10 hours	40%
12	9.54 hours	9.5 hours	58%
13	9.46 hours	9.5 hours	60%
14	9.15 hours	9.5 hours	33%

This indicates that a great deal of children are not obtaining the recommended sleep duration according to The Sleep Medicine and Research Center (2013). It is recommended that 9-11 year olds receive 10 hours and 12-14 year olds receive 9.5 hours of sleep per night. Specifically, the majority of 11 and 14 year olds are not meeting the recommended sleep requirements. There are only three 14 year olds within the total sample which indicates that only one is obtaining the recommended number of hours. The 11 year olds account for the majority of the sample (45%) and are receiving on average 0.29 hours, or 17.4 minutes, less than the recommendation.

4.2 Home Environment Characteristics

A series of descriptive statistics for the characteristics of the home environments at each buffer extent were computed for ease of comparison between the buffers and are displayed in Table 5. With respect to the land use mix, the value presented is the percentage of each land use within the buffered area.

Table 5: Descriptive statistics of environmental variables at each buffer extent

Variable	500m	800m	1000m	1600m
Average # of children per household	1.2	1.2	1.2	1.2
Number of trees	722.5	1785.6	2710.9	6558.5
Average NDVI reading	0.15	0.17	0.17	0.17
Park space	8.5%	9.7%	10%	10.6%
Land use mix:				
Commercial space	5.3%	5.6%	5.8%	6.1%
Institutional space	6.8%	6.8%	6.9%	7.3%
Residential space	52.3%	48.2%	46.1%	41.5%

Recreational space	12.1%	14.8%	15.8%	17.6%
Industrial space	2.7%	3.4%	3.7%	5.1%
Agricultural space	0.77%	1.1%	1.34%	2.17
Maximum traffic volume (vehicles/day)	21 000	27 600	30 200	35 700
Road connectivity (# intersections)	33.8	79.2	118.2	274.5

4.3 Statistical Analyses

The results of the Shapiro-Wilk test of normality concluded that the data are not a normally distributed sample (see Appendix C for full table). Therefore, non-parametric bivariate tests were used as necessary. The Spearman's Rank Correlation was used to calculate the bivariate relationship between the outcome measure (sleep duration) and the continuous non-normalized independent variables. The Wilcoxon-Mann-Whitney Test was used to calculate the bivariate relationships between the dependent variable (sleep duration) and the categorical independent variables. Lastly, the Kruskal Wallis test was used to test the relationship between sleep duration and the categorical independent variables with more than two groups.

The results indicate that few variables significantly relate to children's sleep duration (refer to Appendix D: Neighbourhood Level Analysis for full result tables). Of the individual level variables age, ethnicity, and a child's BMI z-score were significantly related to sleep duration. Age was inversely correlated with sleep duration, meaning that with each additional year increase of age sleep duration would decrease (-0.16, $p<0.01$). Non-visible minority students receive more sleep than expected while visible minority students obtain less than expected ($p<0.01$). A child's BMI z-score was negatively associated with sleep duration (-0.09, $p=0.05$).

Several individual and behavioural level variables were significantly related to sleep duration. The correlations will be presented with reference to the 1600m buffer, the distance threshold beyond which the local school boards will provide elementary students with bus service to/from their school. The amount of screen time viewed per day (-15.77, $p<0.01$) and commute time to school (-0.16, $p<0.01$) had inverse relationships with sleep duration. That is, children who spend more time viewing screens and spend more time travelling to school spend less time sleeping than their counterparts. School starting time was found to have a positive correlation with sleep duration (0.13, $p<0.01$); indicating that the later the start time the longer the sleep duration. Active commuters on average sleep more than expected, while inactive commuters sleep significantly less than expected ($p<0.01$). The average number of children per household was the only neighbourhood level sociodemographic variable to have a significant association with sleep duration. The correlation was positive (0.09 $p=0.03$), meaning that as the average number of children within the household increased, so did a child's average sleep duration. Of the environmental variables under examination, the amount of institutional space within the surrounding neighbourhood was the sole environmental variable significantly related to sleep duration. This correlation was also positive (0.09 $p=0.04$) suggesting that more institutional space (e.g., schools) results in longer sleep durations.

4.3.1 Multiple Linear Regression Analyses

Hierarchical multiple linear regressions were run at the four buffer extents to determine if an association exists between children's average sleep duration and various individual, socioeconomic, behavioural, neighbourhood level sociodemographic, and neighbourhood level environmental level variables. The regression models included variables that significantly related to children's sleep duration (from the bivariate tests), as well as variables which have been deemed significant to children's sleep duration in previous literature even if these variables were not significantly related within this dataset. Four models were run, with each model adding additional predictor variables.

Model 1: Model 1 included individual level and socioeconomic variables. Age, ethnicity, and BMI z-score were significantly related to sleep duration, and were therefore automatically included. Although not significant, the variables sex and parental income were added as they are significantly related to children's sleep duration in previous literature (Dollman et al., 2007; Spilsbury et al., 2004).

Model 2: The individual and behavioural level variables were added at model 2. The amount of screen time per day, the length of commute time to school, active vs. inactive commuters, and school start times were significantly related to sleep duration, so were included into the model.

Model 3: The neighbourhood level sociodemographic variables were added into the regression at model 3. The average number of children per household was the only variable added.

Model 4: The neighbourhood level environmental variables were the final set added into the regression. The average NDVI value, tree count, the amount of park space, land use mix (commercial, institutional, residential, industrial, and agricultural), home location according to an urban/suburban/rural classification, the average neighbourhood maximum traffic volume, and the amount of road connectivity within the buffer. Although these variables were not significantly related to sleep duration they were included within the regression, as these are the primary variables being explored for this thesis.

Testing for multicollinearity between the independent variables showed a high correlation between the amount of park space and the amount of recreational space. Since park space is a measure of green space (the primary independent variable of interest), this variable was included while recreational space was omitted.

Tables 7, 8, 9, and 10 present the results of the multiple regression models estimating the relative effects of individual, socioeconomic, behavioural, neighbourhood level sociodemographic, and neighbourhood level environmental factors on children's sleep duration at four buffer extents. Since the number of observations drops to 406 for the final model (due to missing data), the number of independent variables was reduced. Therefore, environmental variables with the highest p values and were not the primary variables of interest were eliminated (i.e. the amount of water bodies, the amount of building space, the length of sidewalks, the length of bike paths, the length of roads, and the length of multi-use pathways). The variables included into the model statistically significantly predicted children's sleep duration (at the final model):

500m: $F(29, 377) = 3.95$, $p<0.01$, $R^2 = 0.2369$

800m: $F(29, 377) = 3.85$, $p<0.01$, $R^2 = 0.2298$

1000m: $F(29, 377) = 3.96$, $p<0.01$, $R^2 = 0.2340$

1600m: $F(29, 377) = 3.77$, $p<0.01$, $R^2 = 0.2327$

The results of the multiple regressions at each buffer size are similar with minor variations between them, with the exception of the 1600m buffer. With reference to

Tables 7, 8, 9, and 10 the adjusted R-squared value shows that for the final model 17.69%, 17.01%, 17.49%, and 17.36% of the variability in sleep duration is explained by the model and variables within it at buffer size 500m 800m, 1000m and 1600m respectively. Table 6 shows a breakdown of the significant associations with average sleep duration at the various buffer sizes. The following sections expand on the relationships found in each of the models - with specific reference to the 1600m level as this buffer extent yielded the most environmental variables which were significantly associated with the outcome measure.

Table 6: Report of Significance at Model 4 of Multiple Regression Output

Independent Variables	500m	800m	1000m	1600m
Age	✓	✓	✓	✓
Sex	X	X	X	✓
Income	X	X	X	X
Ethnicity	✓	✓	✓	✓
BMI z-score	✓	✓	✓	✓
Screen time	✓ (6+ hours)	✓ (6+ hours)	✓ (6+ hours)	✓ (6+ hours)
Commute time	✓	✓	✓	✓
Inactive commuters	X	X	X	X
School start time	✓	✓	✓	✓
Average number of children/household	✓	✓	✓	✓
Tree count	X	X	X	X
NDVI	X	X	X	✓
Park space	X	X	X	✓
Commercial space	X	X	X	X
Institutional space	X	X	X	X
Residential space	X	X	X	✓
Industrial space	X	X	X	X
Urban	X	X	✓ (Suburban)	✓ (Suburban)
Maximum traffic volume	X	X	X	X
Road connectivity	X	X	X	X

Note: "✓" *represents variables that were significantly related to children's sleep duration,* "X" *signifies a non-significant relationship.*

Individual Level and Socioeconomic Variables:

In model 1, sex and parental income were not associated with children's sleep duration. These variables continue to have no impact on children's sleep duration within models 2, 3 and 4. However, model 4 of the 1600m buffer, females were found to obtain 10.45 additional minutes of sleep compared to their male counterparts (p=0.03). Age and sleep duration are found to consistently have a strong, negative relationship throughout the four models and at each buffer extent. With reference to the results at the 1600m buffer (Table 10), with each additional year increase in age the amount of sleep received decreases by 10.57 minutes (p<0.01). This negative influence of age and sleep duration is understandable because bedtime curfews will often be later for older children, thus the sleep duration will be shorter. Ethnicity is also found to be consistently associated with average sleep duration. With respect to model 4 at the 1600m buffer, students of visible minority status typically obtain 16.1 fewer minutes of sleep than students of non-visible minority status (p<0.01). Children's BMI z-score was significantly related to children's overall sleep duration. This relationship was inversely related (-4.80; p=0.01); indicating that with each unit of increase in BMI z-score (i.e. 0.0-1.0) children obtain approximately 4.80 fewer minutes of sleep.

Individual and Behavioural Level Variables:

Variability between the buffer sizes and models was minimal when examining the individual and behavioural level variables. The amount of time spent viewing screens has a significant inverse relationship with sleep duration, indicating that over 6 hours of screen time per day is predicted to result in 35.61 less minutes of sleep ($p<0.01$), compared to viewing less than two hours of daily screen time.

Commute time to school had a strong inverse relationship with total sleep duration (-0.71; $p<0.01$). For instance, an increase in commute time of 15 minutes would result in a decrease of sleep time by 10.65 minutes. School start times is significantly related to the amount of sleep the child receives (0.58; $p<0.01$). For each minute of later school start times there is an increase in sleep duration of 0.58 minutes. Therefore, a school starting 30 minutes later would equate to 17.4 extra minutes of sleep for children of this age group. Inactive commuters did not produce a statistically significant relationship with sleep duration (-8.42; $p=0.16$), thus indicating that whether a child commutes to school actively (for example walking or riding a bike) or inactively (for example by car or bus) does not have an influence on the sleep length they obtain.

Neighbourhood Level Sociodemographic Variables:

Consistently across all buffer sizes and models, the average number of children per household was significantly related to children's sleep duration. At the 1600m buffer the relationship indicates that an additional 25.46 minutes of sleep will be obtained with each one unit increase in mean number of children per household per DA (for instance a one unit increase would be a mean of 1.1 children to a mean of 2.1 children).

Neighbourhood Level Environmental Variables:

The results for environmental variables were unexpected as very few variables were significantly associated with sleep duration. At the 500 m and 800 m buffer size, all environmental factors are statistically insignificant (Table 7 and Table 8). At the 1000 m and 1600 m buffer extents, living in a suburban neighbourhood was significantly related to children's sleep duration. This relationship indicates that if a participant's home was located in a suburban (versus urban) neighbourhood, they obtain an increase of 15.42 (p=0.04 at 1000m buffer) or 20.52 (p=0.02 at 1600m buffer) minutes of sleep.

With respect to the green space variables, NDVI has a positive relationship with sleep duration – at the 1600m buffer - indicating that with each unit increase in the mean NDVI value, a 8.02 minute (p=0.05) increase in sleep duration is observed. The amount of park space (1000 m^2) also became significant at the 1600m buffer size (-0.00, p=0.01). This finding was unexpected as it was inversely associated with sleep duration while the literature suggests the opposite would have been found. The coefficient is negligible (-0.00) and the beta value is fairly low (-0.08) suggesting that this inverse association is minimal. The number of city owned trees in the neighbourhood buffer remained statistically insignificant.

Of the other built environmental variables residential space was the sole variable to become significant within the model. At the 1600 m buffer extent the amount of residential space was significant (-0.00, p=0.04). This indicates that with each 1000 m^2 increase of residential space a decrease in sleep duration is obtained, but only by a miniscule amount. All other environmental variables were insignificantly related to the sleep duration of children in this sample. Institutional land use, industrial land use, agricultural land use, maximum traffic volume, and road connectivity are close to being significant; however, these relationships are not consistent across the four buffer sizes.

4.4 Conclusion

The results reveal some relationships that are expected and some unexpected based on the literature. The individual level and behavioural variables, similarly related across all four buffers, were found to be significantly associated with sleep duration. For instance, it was found that a child's commute time to school and their school's start time had a significant impact on their average duration of sleep. No environmental variables were associated with children's sleep duration for the three smallest buffers (500 m, 800 m, and 1000 m), with the exception of living in a suburban neighbourhood at the 1000 m buffer extent. It was not until the 1600 m buffer extent was considered that environmental variables appeared to be significant. Of the green space variables NDVI did have a positive impact on children's sleep duration at the 1600 m buffer while the amount of park space had a negative association (if any as the coefficient was -0.00). Tree count was insignificant. In other words, opportunity to green space did have a positive significant impact on children's sleep duration in this study with respect to NDVI.

The lack of relationships displayed for the environmental variables may be a result of the Euclidean buffer approach. Buffers (Euclidean or otherwise), are a commonly used technique for examining the environmental characteristics of an area of a selected distance around a specific location (e.g., home or school). Buffers are fairly straightforward to generate and analyze using desktop GIS software; however, they only measure availability of a certain environmental feature in an area or opportunity for exposure. Although widely used in environment and health studies, the buffer method may not provide an accurate estimation of what environmental features an individual is truly exposed to during a given time period (e.g., during the journey to and from school).

The next chapter will adopt a more sophisticated method to capture exposure to various environments. This will determine whether the results of this chapter were influenced by methodological limitations or reflect a genuine lack of relationship between sleep and certain environmental factors such as green space.

Table 7: Results of Multiple Regression at 500m buffer

	Model 1			Model 2			Model 3			Model 4		
	B	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**
Individual Level and Sociodemographic Variables:												
Age	**-9.59**	**<0.01**	**-0.17**	**-9.27**	**<0.01**	**-0.17**	**-8.73**	**<0.01**	**-0.16**	**-7.68**	**<0.01**	**-0.13**
Female	5.73	0.18	0.06	7.79	0.08	0.08	9.65	0.06	0.09	9.45	0.12	0.09
Ethnicity:												
Visible minority	**-12.65**	**<0.01**	**-0.15**	**-14.10**	**<0.01**	**-0.14**	**-14.19**	**<0.01**	**-0.13**	**-13.90**	**<0.01**	**-0.13**
Prefer not to say	-8.30	0.12	-0.07	-8.83	0.18	-0.06	-7.77	0.24	-0.06	-7.42	0.28	-0.05
Income:												
$40,000 – 79,000	-4.41	0.68	-0.03	5.29	0.63	0.03	5.64	0.61	0.04	8.89	0.43	0.06
$80,000 – 129,000	-8.26	0.43	-0.05	-3.16	0.77	-0.02	-2.39	0.82	-0.02	-2.56	0.82	-0.02
$130,000 +	-1.22	0.91	-0.01	2.72	0.81	0.02	2.22	0.84	0.01	6.66	0.57	0.04
Prefer not to say	-1.50	0.86	-0.01	3.75	0.69	0.03	4.48	0.63	0.04	6.46	0.49	0.06
BMI z-score	**-4.62**	**0.02**	**-0.11**	**-4.54**	**0.02**	**-0.11**	**-4.49**	**0.02**	**-0.11**	**-4.34**	**0.03**	**-0.11**
Individual and Behavioural Variables:												
Screen time / day:												
2.1-4 hours				-0.07	0.91	-0.01	-1.20	0.89	-0.01	-2.06	0.81	-0.02
4.1 – 6 hours				-1.23	0.89	-0.01	-2.32	0.80	-0.02	-3.00	0.75	-0.02
6.1 + hours				**-35.01**	**<0.01**	**-0.19**	**-33.48**	**<0.01**	**-0.16**	**-36.33**	**<0.01**	**-0.18**
No response				-13.64	0.09	-0.08	-14.78	0.07	-0.13	-13.54	0.09	-0.14
Commute time				**-0.52**	**0.03**	**-0.14**	**-0.54**	**<0.01**	**-0.12**	**-0.58**	**<0.01**	**-0.13**
Inactive commuters				-10.50	0.08	-0.09	-10.05	0.10	-0.09	-9.99	0.11	-0.09
School start time				**0.43**	**<0.01**	**0.14**	**0.48**	**<0.01**	**0.14**	**0.48**	**<0.01**	**0.14**
Neighbourhood Level Sociodemographic Variables:												
Average # of children/household							**19.51**	**<0.01**	**0.11**	**11.12**	**0.02**	**0.06**
Neighbourhood Level Environmental Variables:												
Tree count										0.00	0.33	-0.05
NDVI										1.01	0.77	0.02
Park space										-0.03	0.39	-0.05
Commercial space										0.02	0.76	0.02
Institutional space										0.09	0.07	0.10
Residential space										-0.04	0.15	-0.09
Industrial space										-0.08	0.15	-0.08

	Model 1			Model 2			Model 3			Model 4		
	B	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**
Agricultural space										-0.10	0.11	-0.09
Urban:												
Suburban										13.53	0.09	0.11
Rural										11.28	0.68	-0.01
Maximum traffic volume										-0.55	0.06	-0.08
Road connectivity										0.46	0.08	0.13
N		**525**			**406**			**406**			**406**	
Constant		**700.00**			**462.86**			**417.71**			**416.73**	
Adjusted R^2		**0.053**			**0.139**			**0.147**			**0.1769**	

* Ethnicity base: non-visible minority; income base: <$20,000 – 39,000; screen time base: less than 2 hours; urban base: urban setting

Table 8: Results of Multiple Regression at 800m buffer

	Model 1			Model 2			Model 3			Model 4		
	B	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**
Individual Level and Socioeconomic Variables:												
Age	**-9.59**	**<0.01**	**-0.17**	**-9.27**	**<0.01**	**-0.17**	**-8.73**	**<0.01**	**-0.16**	**-7.81**	**<0.01**	**-0.13**
Female	5.73	0.18	0.06	7.79	0.08	0.08	9.65	0.06	0.09	7.87	0.12	0.09
Ethnicity:												
Visible minority	**-12.65**	**<0.01**	**-0.15**	**-14.10**	**<0.01**	**-0.14**	**-14.19**	**<0.01**	**-0.13**	**-14.78**	**<0.01**	**-0.14**
Prefer not to say	-8.30	0.12	-0.07	-8.83	0.18	-0.06	-7.77	0.24	-0.06	-9.20	0.16	-0.07
Income:												
$40,000 – 79,000	-4.41	0.68	-0.03	5.29	0.63	0.03	5.64	0.61	0.04	6.92	0.53	0.04
$80,000 – 129,000	-8.26	0.43	-0.05	-3.16	0.77	-0.02	-2.39	0.82	-0.02	-2.93	0.79	-0.02
$130,000 +	-1.22	0.91	-0.01	2.72	0.81	0.02	2.22	0.84	0.01	4.42	0.70	0.03
Prefer not to say	-1.50	0.86	-0.01	3.75	0.69	0.03	4.48	0.63	0.04	5.28	0.57	0.05
BMI z-score	**-4.62**	**0.02**	**-0.11**	**-4.54**	**0.02**	**-0.11**	**-4.49**	**0.02**	**-0.11**	**-4.45**	**0.02**	**-0.11**
Individual and Behavioural Variables:												
Screen time / day:												
2.1-4 hours				-0.07	0.91	-0.01	-1.20	0.89	-0.01	-0.07	0.82	-0.02
4.1 – 6 hours				-1.23	0.89	-0.01	-2.32	0.80	-0.02	-1.23	0.80	-0.02
6.1 + hours				**-35.01**	**<0.01**	**-0.19**	**-33.48**	**<0.01**	**-0.16**	**-35.01**	**<0.01**	**-0.18**
No response				-13.64	0.09	-0.08	-14.78	0.07	-0.13	-13.64	0.08	-0.13
Commute time				**-0.52**	**0.03**	**-0.14**	**-0.54**	**<0.01**	**-0.12**	**-0.52**	**<0.01**	**-0.15**
Inactive commuters				-10.50	0.08	-0.09	-10.05	0.10	-0.09	-10.50	0.13	-0.08
School start time				**0.43**	**<0.01**	**0.14**	**0.48**	**<0.01**	**0.14**	**0.43**	**<0.01**	**0.17**
Neighbourhood Level Sociodemographic Variables:												
Average # of children/household							**19.51**	**<0.01**	**0.11**	**17.05**	**0.05**	**0.10**
Neighbourhood Level Environmental Variables:												
Tree count										0.00	0.31	-0.06
NDVI										0.80	0.82	0.01
Park space										-0.01	0.44	-0.04
Commercial space										0.01	0.68	0.02
Institutional space										0.04	0.08	0.09
Residential space										-0.02	0.15	-0.09
Industrial space										-0.04	0.08	-0.11
Agricultural space										-0.04	0.09	-0.10

	Model 1			Model 2			Model 3			Model 4		
	B	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**
Urban:												
Suburban										14.92	0.08	0.11
Rural										26.08	0.32	0.05
Maximum traffic volume										-0.24	0.42	-0.05
Road connectivity										0.21	0.22	0.08
N		**525**			**406**			**406**			**406**	
Constant		**694.07**			**475.23**			**404.49**			**403.83**	
Adjusted R^2		**0.053**			**0.139**			**0.147**			**0.1701**	

* Ethnicity base: non-visible minority; income base: <$20,000 – 39,000; screen time base: less than 2 hours; urban base: urban setting

Table 9: Result of Multiple Regression at 1000m buffer

	Model 1			**Model 2**			**Model 3**			**Model 4**		
	B	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**
Individual Level and Socioeconomic Variables:												
Age	**-9.59**	**<0.01**	**-0.17**	**-9.27**	**<0.01**	**-0.17**	**-8.73**	**<0.01**	**-0.16**	**-8.20**	**<0.01**	**-0.13**
Female	5.73	0.18	0.06	7.79	0.08	0.08	9.65	0.06	0.09	7.88	0.11	0.09
Ethnicity:												
Visible minority	**-12.65**	**<0.01**	**-0.15**	**-14.10**	**<0.01**	**-0.14**	**-14.19**	**<0.01**	**-0.13**	**-15.03**	**<0.01**	**-0.14**
Prefer not to say	-8.30	0.12	-0.07	-8.83	0.18	-0.06	-7.77	0.24	-0.06	-8.73	0.18	-0.06
Income:												
$40,000 – 79,000	-4.41	0.68	-0.03	5.29	0.63	0.03	5.64	0.61	0.04	6.57	0.55	0.04
$80,000 – 129,000	-8.26	0.43	-0.05	-3.16	0.77	-0.02	-2.39	0.82	-0.02	-2.80	0.79	-0.02
$130,000 +	-1.22	0.91	-0.01	2.72	0.81	0.02	2.22	0.84	0.01	3.19	0.78	0.02
Prefer not to say	-1.50	0.86	-0.01	3.75	0.69	0.03	4.48	0.63	0.04	5.18	0.58	0.05
BMI z-score	**-4.62**	**0.02**	**-0.11**	**-4.54**	**0.02**	**-0.11**	**-4.49**	**0.02**	**-0.11**	**-4.60**	**0.02**	**-0.11**
Individual and Behavioural Variables:												
Screen time / day:												
2.1-4 hours				-0.07	0.91	-0.01	-1.20	0.89	-0.01	-1.88	0.82	-0.02
4.1 – 6 hours				-1.23	0.89	-0.01	-2.32	0.80	-0.02	-2.30	0.80	-0.02
6.1 + hours				**-35.01**	**<0.01**	**-0.19**	**-33.48**	**<0.01**	**-0.16**	**-35.99**	**<0.01**	**-0.18**
No response				-13.64	0.09	-0.08	-14.78	0.07	-0.13	-16.09	0.06	-0.14
Commute time				**-0.52**	**0.03**	**-0.14**	**-0.54**	**<0.01**	**-0.12**	**-0.54**	**<0.01**	**-0.12**
Inactive commuters				-10.50	0.08	-0.09	-10.05	0.10	-0.09	-9.32	0.14	-0.08
School start time				**0.43**	**<0.01**	**0.14**	**0.48**	**<0.01**	**0.14**	**0.52**	**<0.01**	**0.15**
Neighbourhood Level Sociodemographic Variables:												
Average # of children/household							**19.51**	**<0.01**	**0.11**	**19.88**	**0.02**	**0.11**
Neighbourhood Level Environmental Variables:												
Tree count										0.00	0.36	-0.06
NDVI										5.11	0.19	0.07
Park space										-0.00	0.46	-0.04
Commercial space										0.02	0.24	0.07
Institutional space										0.03	0.11	0.09
Residential space										-0.01	0.41	-0.05
Industrial space										-0.02	0.09	-0.11
Agricultural space										-0.03	0.06	-0.11

	Model 1			Model 2			Model 3			Model 4		
	B	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**
Urban:												
Suburban										**15.42**	**0.04**	**0.12**
Rural										18.78	0.43	0.02
Maximum traffic volume										-0.22	0.51	-0.04
Road connectivity										0.12	0.36	0.07
N	**525**			**406**			**406**			**406**		
Constant	**694.70**			**475.23**			**417.71**			**371.40**		
Adjusted R^2	**0.053**			**0.139**			**0.147**			**0.1749**		

* Ethnicity base: non-visible minority; income base: <$20,000 – 39,000; screen time base: less than 2 hours; urban base: urban setting

Table 10: Result of Multiple Regression at 1600m buffer

	Model 1			Model 2			Model 3			Model 4		
	B	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**
Individual Level and Socioeconomic Variables:												
Age	**-9.59**	**<0.01**	**-0.17**	**-9.27**	**<0.01**	**-0.17**	**-8.73**	**<0.01**	**-0.16**	**-10.57**	**<0.01**	**-0.19**
Female	5.73	0.18	0.06	7.79	0.08	0.08	9.65	0.06	0.09	**10.45**	**0.03**	**0.10**
Ethnicity:												
Visible minority	**-12.65**	**<0.01**	**-0.15**	**-14.10**	**<0.01**	**-0.14**	**-14.19**	**<0.01**	**-0.13**	**-16.10**	**<0.01**	**-0.15**
Prefer not to say	-8.30	0.12	-0.07	-8.83	0.18	-0.06	-7.77	0.24	-0.06	-9.20	0.16	-0.07
Income:												
$40,000 – 79,000	-4.41	0.68	-0.03	5.29	0.63	0.03	5.64	0.61	0.04	4.19	0.70	0.03
$80,000 – 129,000	-8.26	0.43	-0.05	-3.16	0.77	-0.02	-2.39	0.82	-0.02	-4.95	0.64	-0.03
$130,000 +	-1.22	0.91	-0.01	2.72	0.81	0.02	2.22	0.84	0.01	-1.73	0.88	-0.01
Prefer not to say	-1.50	0.86	-0.01	3.75	0.69	0.03	4.48	0.63	0.04	2.93	0.75	0.03
BMI z-score	**-4.62**	**0.02**	**-0.11**	**-4.54**	**0.02**	**-0.11**	**-4.49**	**0.02**	**-0.11**	**-4.80**	**0.01**	**-0.12**
Individual and Behavioural Variables:												
Screen time / day:												
2.1-4 hours				-0.07	0.91	-0.01	-1.20	0.89	-0.01	-2.43	0.77	-0.02
4.1 – 6 hours				-1.23	0.89	-0.01	-2.32	0.80	-0.02	-1.80	0.84	-0.01
6.1 + hours				**-35.01**	**<0.01**	**-0.19**	**-33.48**	**<0.01**	**-0.16**	**-35.61**	**<0.01**	**-0.17**
No response				-13.64	0.09	-0.08	-14.78	0.07	-0.13	-8.52	0.28	-0.11
Commute time				**-0.52**	**0.03**	**-0.14**	**-0.54**	**<0.01**	**-0.12**	**-0.71**	**<0.01**	**-0.16**
Inactive commuters				-10.50	0.08	-0.09	-10.05	0.10	-0.09	-8.42	0.16	-0.09
School start time				**0.43**	**<0.01**	**0.14**	**0.48**	**<0.01**	**0.14**	**0.58**	**<0.01**	**0.19**
Neighbourhood Level Sociodemographic Variables:												
Average # children/household							**19.51**	**<0.01**	**0.11**	**25.46**	**<0.01**	**0.17**
Neighbourhood Level Environmental Variables:												
Tree count										0.00	0.80	0.02
NDVI										**8.02**	**0.05**	**0.09**
Park space										**-0.00**	**0.01**	**-0.08**
Commercial space										0.02	0.09	0.10
Institutional space										0.01	0.08	0.09
Residential space										**-0.00**	**0.04**	**-0.07**
Industrial space										-0.00	0.58	-0.04
Agricultural space										-0.01	0.14	-0.11

	Model 1			**Model 2**			**Model 3**			**Model 4**		
	B	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**
Urban:												
Suburban										**20.52**	**0.02**	**0.18**
Rural										14.05	0.18	0.08
Maximum traffic volume										-0.12	0.80	0.02
Road connectivity										-0.03	0.41	0.05
N		**525**			**406**			**406**			**406**	
Constant		**695.51**			**475.44**			**418.01**			**378.48**	
Adjusted R^2		**0.053**			**0.139**			**0.147**			**0.1736**	

* Ethnicity base: non-visible minority; income base: <$20,000 – 39,000; screen time base: less than 2 hours; urban base: urban setting

Chapter 5 Individual Level Results: Examining the Impact of Individual Level Factors and Exposure to Green Space on Children's Sleep Duration

In Chapter 4 it was found that individual and behavioural level variables had the greatest association with sleep duration. For instance, a child's age, their BMI z-score, their commute time to school, and the school's starting time all significantly impacted their sleep duration. Environmental variables did not have a strong impact on their sleep duration – the few of which only appeared significant at the 1000 m and 1600 m neighbourhood buffer level. Given the unexpected finding that green space and other built environmental features had a limited impacted on sleep duration, a more in-depth exploration is necessary. This chapter presents the findings from an analysis of individual level environmental exposure. The purpose of the individual level exposure analysis was to improve upon the buffer technique that is commonly used in previous studies and was used in the previous chapter.

Although the details of the methods for this chapter are fully outlined in Chapter 3, a brief overview is worth repeating here as a reminder. Children participating in the STEAM project wore a GPS logger for seven consecutive days in order to capture where they go and where they spend their time in a typical week. Within a GIS, the individual location points recorded by GPS tracking were spatially-aggregated into their respective individual hexagonal cells (20m in width) within a tessellated hexagonal grid surface which was superimposed over the entire geographic area representing the City of London. The environmental characteristics of each hexagonal cell were also calculated in GIS. This spatial analysis technique allowed for the examination of if and how individual level exposure to different environmental factors effected children's sleep duration. The results were generated through analysis done with ArcGIS (version 10.1) and Stata (version 13.0). This analytical approach seeks to address the overarching research question: to what extent do green spaces and other built environmental features impact children's sleep duration? This approach will also address the final supplementary research question: is children's sleep duration impacted by their daily exposure to green space?

5.1 Participants

Students who participated in the spring 2010, 2011, 2012 and 2013 seasons of the STEAM project were eligible for inclusion (n=614). Of those eligible, 514 students (83.7%) were included for this part of the study. The 100 students were omitted because of either: missing GPS data tracks to measure exposure space (n=32), the student's home location fell outside the City of London's boundary (n=42), or the student did not have adequate recorded sleep data (n=26). Characteristics of the sample are provided in Table 11.

Table 11: Sample Characteristics

Sample Characteristics (n=514)	Number (n, %)
Age, n (%)	
9	9 (1.71)
10	81 (15.76)
11	223 (44.19)
12	154 (29.33)
13	46 (8.95)
14	1 (0.06)
Sex, n (%)	
Male	203 (39.49)
Female	311 (60.51)
Ethnicity, n (%)	
Non-Visible Minority	248 (48.21)

Visible Minority	96 (18.72)
Prefer not to say	170 (33.06)
Parental Income, n (%)	
<$20,000 – 39,000	44 (8.56)
$40,000 – 79,000	62 (12.06)
$80,000 – 129,000	68 (13.22)
+$130, 000	64 (12.45)
Prefer not to say	276 (53.69)
BMI Z-Score, μ	0.14
Screen Time / day, n (%)	
<2 hours	65 (12.65)
2.1 – 4 hours	78 (15.18)
4.1 – 6 hours	74 (14.40)
6.1 + hours	71 (13.81)
Prefer not to say	226 (43.96)
Commute time to school, μ minutes	14.85
Commute Mode, n (%)	
Active	186 (36.15)
Inactive	328 (63.85)
School Start Time	8:57 am
Neighbourhood Classification, n (%)	
Urban	88 (17.12)
Suburban	419 (81.52)
Rural	7 (1.36)

The sample characteristics of the students are similar to that of the previous results chapter (Chapter 4), with 52% of the study population being of non-visible minority. The average commute time was 14.9 minutes to school with 64% of individuals taking inactive modes to school (the most popular mode by school bus at 38%). The average sleep duration was 581.32 minutes (9.69 hours). The average sleep duration on weekends was 587.92 minutes (9.80 hours) and 578.79 minutes (9.65 hours) on weekdays, averaging to an additional 9.13 minutes of sleep on the weekends. Table 12 presents a series of descriptive statistics of the environmental variables which children were exposed to on a daily basis.

Table 12: Descriptive statistics of the environmental variables

Variable	Number
Average weighted NDVI reading exposed to / day	0.0003
Proportion of time in hexagon with NDVI (>0.15)	28.1%
Proportion of time spent in NDVI levels:	
low NDVI area (0.0-0.002)	28.52%
medium NDVI area (0.0021-0.1)	30.87%
high NDVI area (0.11-1.0)	40.61%
Proportion of time in park areas	33.22%
Average weighted number of trees exposed to daily	0.001
Proportion of time in hexagon with >1 tree	10.00%
Proportion of time spent in hexagon by tree count levels:	
low number of trees (0-2 trees)	90.40%
medium number of trees (3-5 trees)	7.50%
high number of trees (6+)	2.10%
Proportion of time spent in hexagon with:	
Bike paths	2.41%
Roads	17.80%
Sidewalks	15.04%
Multi-use paths	0.34%
Water bodies	0.16%
Buildings	67.24%
Average number of road intersections exposed to	9.53e-04
Proportion of time exposed to traffic volumes >10,000	3.48%
Proportion of time spent in hexagon with:	

agricultural area	4.19%
residential area	61.01%
recreational area	4.38%
commercial area	9.20%
institutional area	18.87%
industrial area	2.36%

5.2 Statistical Analyses

Application of the Shapiro-Wilk test of normality determined that the data is not normally distributed; thus non-parametric tests will be used where applicable (refer to Appendix C for the full table). Due to the variety of independent variables under investigation, different statistical bivariate tests were run to test the association with sleep duration. Spearman's Rank Correlation was run on continuous independent variables, the Wilcoxon-Mann-Whitney Test was run on categorical independent variables, and the Kruskal Wallis Test was run on categorical variables with more than two groups.

Results of the bivariate correlations (refer to Appendix D: Individual Level Analysis for full results) showed that more variables, compared to the neighbourhood level analysis, were significantly related to children's daily sleep duration. Of the individual level variables, age (-0.14, $p<0.01$), ethnicity (4.39, $p<0.01$), and BMI z-scores (-0.04, $p=0.04$) were significantly related to the outcome measure. Visible minority students are obtaining less sleep than expected, while non-visible minority students are obtaining more sleep than expected. Several individual and behavioural level variables were significantly correlated. Commute time to school (-0.12, $p<0.01$) was inversely correlated to sleep duration. School start time (0.08, $p<0.01$) had a positive relationship with sleep duration, indicating that the later the child starts school, the more time they will spend sleeping. Amount of daily screen time (-35.02, $p<0.01$) had an inverse association with sleep duration; the more time spent in front of screens the shorter the sleep duration. Active commuters tend to sleep more than expected while the inactive commuters are sleeping less than expected (5.05, $p<0.01$). Sedentary physical activity counts (-0.13, $p<0.01$) were inversely associated with sleep duration while moderate (0.05, $p=0.01$) and moderate to vigorous physical activity counts (0.05, $p=0.01$) were positively associated.

Of the neighbourhood sociodemographic level data, average number of children (aged 0-19 years) within the household (0.05, $p<0.01$), percentage of people aged 0-19 (0.04, $p=0.03$), and percentage of middle income families within the neighbourhood (0.04, $p=0.04$) were significantly related to daily sleep duration. A child's home location (categorized as urban, suburban or rural) was also significantly associated with sleep duration (8.107, $p=0.02$) as identified by the Kruskal-Wallis test.

Many environmental features were significantly related to children's daily sleep duration within this sample; however, the magnitude of the relationships is weak. Average daily NDVI exposure (0.07, $p<0.01$) had a positive association, indicating that children with greater NDVI exposure tended to have longer sleep durations. Unexpectedly, the proportion of time spent in a hexagon with greater than one tree had an inverse association (-0.04, $p=0.05$). This indicates that less sleep tended to be obtained with more time spent in hexagons with trees. The proportion of time spent in hexagons with: bike paths (-0.09, $p<0.01$), road areas (-0.07, $p<0.01$), sidewalks (-0.05, $p<0.01$), water bodies (-0.07, $p<0.01$), exposed to traffic volumes greater than 10,000 (-0.08, $p<0.01$), agricultural areas (-0.05, $p<0.01$), commercial areas (-0.08, $p<0.01$), and industrial areas (-0.09, $p<0.01$) all had inverse associations with sleep duration. The proportion of time spent in hexagons with buildings (0.04, $p=0.04$) had a positive association, suggesting that the more time spent exposed to buildings the longer the sleep duration. It is worth noting that this variable includes time spent within one's own home. Time spent in hexagons with institutional spaces also had a positive correlation with sleep duration (0.09, $p<0.01$), indicating that more time spent in institutional areas resulted in longer sleep durations.

5.2.1 Multiple Linear Regression

A hierarchical multiple linear regression was conducted to determine the association between children's daily sleep duration and various individual, socioeconomic, behavioural, neighbourhood sociodemographic, and environmental factors. Four models were run, similar to that conducted in Chapter 4, building successive linear regressions by adding additional predictor variables. Table 13 presents estimates from the regression model for children's daily sleep duration with various predictor variables.

Model 1: Model 1 included individual level and socioeconomic variables. Age, ethnicity, and a child's BMI z-score were included as the bivariate analysis showed a significant association to sleep duration. Although not significant in this data set, sex and parental income were added as both have been found to be significantly related to children's sleep duration in the literature (Dollman et al., 2007; Spilsbury et al., 2004).

Model 2: The individual and behavioural level variables were introduced at model 2. The amount of screen time per day, the length of commute time to school, commute method (active or inactive), school start times, sedentary physical activity counts, and moderate to vigorous physical activity counts were significantly related to sleep duration, so they were introduced into the model. Moderate physical activity counts were not included due to multicollinearity with moderate to vigorous physical activity counts.

Model 3: The neighbourhood level sociodemographic variables were added into the regression at model 3. These included: the average number of children (aged 0-19 years) per household, the percentage of middle income families within the neighbourhood, and whether the child's home was classified as residing in an urban, suburban, or rural neighbourhood. The percentage of people aged 0-19 within the neighbourhood was not included due to multicollinearity with the average number of children per household.

Model 4: The final variables added into the regression model were the environmental variables. These variables include: the average tree exposure, the average number of road intersections exposed to; and the proportion of time spent in green environments, park spaces, commercial spaces, institutional spaces, recreational spaces, residential spaces, industrial spaces, agricultural spaces, roads which have traffic volumes greater than 10,000 cars per day, road areas, sidewalks, multi-use pathways, building areas, and water bodies. Although these variables were not all significantly related to sleep duration (average weighted tree exposure, proportion of time spent in green area, average weighted road intersection exposure, proportion of time spent in residential and recreational area were all not significantly correlated) they were included within the regression as these are the primary variables being explored for this thesis. Although additional measures of green exposure (measured by NDVI) and tree exposure were generated, only one measure was included in the regression due to redundancy. Thus, the variables which produced the strongest correlation with the outcome measure remained in the final regression model. Therefore, the omitted measures of green exposure are: the average-weighted NDVI exposure and the three categories of increasing greenness, and the omitted measures of tree exposure are: time spent in a hexagon with greater than one tree and the three categories (low, medium, and high) of tree exposure.

The multiple regression model with all predictor variables significantly predicted children's sleep duration: F (38, 2571) = 6.05, p=0.00, R^2 = 0.0903. The adjusted R^2 value at the final model was low indicating that of the variables included in the model only 8.6% of the outcome variable can be explained by them. The findings of the multiple regression analyses are described below.

Individual Level and Socioeconomic Variables:

The individual level and socioeconomic variables were added in at model 1 and remained in each of the next subsequent models as predictors. The child's age, sex, ethnicity, and BMI z-score were significantly related to daily sleep duration in all models. After controlling for all other variables (model 4), it was found that with each year increase in age there tended to be a decrease of 8.04 minutes of daily sleep duration (p=0.01). Females slept 10.81 more minutes than their male counterparts (p<0.01). Students of visible minority status obtained 15.23 fewer minutes of sleep (p<0.01) than their non-visible minority student counterparts. With each increase in a child's BMI z-score a reduction of 3.8 minutes of sleep is found ($p<0.01$). Parental income was not significantly related to children's sleep duration in any of the models.

Individual and Behavioural Variables:

Individual and behavioural level variables were added into the regression at model 2. Across all of the models the amount of screen time per day, their commute time to school, and their school starting time remained significantly related to sleep duration. Spending more than 6 hours of time in front of a screen per day was found to negatively impact children's sleep duration. 35.8 fewer minutes of sleep ($p<0.01$) was obtained when 6 or more hours were spent in front of a screen per day compared to less than two hours of screen viewing.

Increased commute time to school was found to decrease children's sleep duration. Each minute increase in commute time resulted in a decrease of 0.59 minutes of sleep duration ($p<0.01$). Hence, a 15 minute longer commute time would reduce sleep duration by 8.85 minutes. Commuting to school by inactive means (for example by car, school bus, or city bus) was found to negatively impact sleep duration. At model 3, children who commute to school inactively experienced shorter sleep durations by 9.66 minutes compared to active commuters ($p=0.02$). However, it did not remain significant after controlling for environmental variables (model 4). School start time was found to have a significant association with sleep duration in all three models. At the final model, it was found that with each minute later in school starting time, there would be an increase in sleep duration (0.53, $p<0.01$). Children would obtain an additional 15.9 minutes of sleep with each 30 minute later school start time.

Sedentary physical activity counts were not significant within models 2 and 3. When environmental variables were added in at model 4, however, the variable became significantly inversely associated with sleep duration (-0.01, p=0.03). This indicates that increasing sedentary physical activity by one minute results in a decrease in sleep duration of 0.01 minutes. The moderate to vigorous physical activity counts variable was not significantly related to sleep duration in any of the models (0.06, p=0.16).

Neighbourhood Level Variables:

The neighbourhood sociodemographic variables were treated as individual neighbourhood level variables in this regression. These variables were added in at model 3 to be consistent with the regression models of the first results chapter (Chapter 4). The average number of children within the household was the only variable significantly related to sleep duration (15.27, p=0.04) in the regression model. This indicates that an additional 15.27 minutes of sleep are obtained with each one unit increase in mean number of children per household (for instance a mean of 1.2 children to a mean of 2.2 children per household). Additionally, whether the child's home location was classified as urban, suburban or rural was added into the regression at model 3. Children residing in suburban neighbourhoods obtained 19.07 additional minutes of sleep compared to those who reside in urban neighbourhoods (p<0.01).

Environmental Variables:

Of the environmental variables under consideration, the proportion of time spent in a hexagon with park spaces was the sole variable which had a significant association with children's sleep duration. Each full percent increase in proportion of time spent in hexagons with park spaces resulted in an increase in sleep duration of 13.4 minutes ($p=0.01$). The two other variables used to measure children's exposure to green spaces – exposure to green areas (where NDVI >0.15) and the average tree count exposure – had positive associations with sleep duration, but both were insignificant (3.41, $p=0.79$; 4.53, $p=0.67$ respectively). The proportion of time spent in hexagons with recreational spaces was also positively associated (10.11); but was not significant ($p=0.13$).

5.3 Conclusion

After a more sophisticated method was applied for measuring a child's exposure to environmental features, exposure to park space was the sole environmental variable found to significantly relate to children's sleep duration. Since park spaces were determined to be a measure of green space exposure, this indicates that a greater amount of time spent exposed to parks (or green spaces areas) results in longer sleep durations. The other two variables used to measure green space for this thesis - proportion of time spent in green areas (measured using NDVI) and the child's average tree exposure - were not significantly associated.

There are a considerable number of individual and behavioural level variables which have a significant impact on children's sleep duration, consistent with the results found in Chapter 4. For example, a child's BMI z-score and commute time to school had an inverse relationship with their sleep duration, while a child's school start time had a positive association. Unexpectedly, exposure to additional environmental variables did not have a significant impact on children's sleep duration. A more in-depth discussion of these findings is presented in the proceeding chapter.

Table 13: Result of Multiple Regression for Environmental Exposure

	Model 1			Model 2			Model 3			Model 4		
	B	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**
Individual Level and Socioeconomic Variables:												
Age	**-9.69**	**<0.01**	**-0.11**	**-8.94**	**<0.01**	**-0.10**	**-8.10**	**<0.01**	**-0.09**	**-8.04**	**<0.01**	**-0.08**
Female	**6.00**	**0.02**	**0.04**	**10.11**	**0.01**	**0.06**	**10.52**	**<0.01**	**0.07**	**10.81**	**<0.01**	**0.07**
Ethnicity:												
Visible minority	**-19.78**	**<0.01**	**-0.10**	**-16.16**	**<0.01**	**-0.08**	**-15.27**	**<0.01**	**-0.08**	**-15.23**	**<0.1**	**-0.11**
Prefer not to say	-9.07	0.01	0.05	-3.03	0.5	-0.01	-2.72	0.6	-0.01	-3.58	0.5	-0.01
Income:												
$40,000 – 79,000	-5.77	0.37	-0.02	-1.89	0.79	-0.01	-1.75	0.81	-0.01	-1.86	0.81	-0.01
$80,000 – 129,000	-11.78	0.06	-0.05	-7.91	0.24	-0.04	-7.44	0.28	-0.03	-8.40	0.25	-0.04
$130,000 +	-4.29	0.51	-0.02	-5.31	0.46	-0.02	-8.14	0.27	-0.04	-4.02	0.61	-0.02
Prefer not to say	-1.90	0.72	-0.01	0.90	0.88	0.01	2.05	0.73	0.01	4.00	0.53	0.03
BMI z-score	**-4.32**	**<0.01**	**-0.07**	**-3.71**	**<0.01**	**-0.06**	**-3.56**	**<0.01**	**-0.06**	**-3.79**	**<0.01**	**-0.07**
Individual and Behavioural Variables:												
Screen time / day:												
2.1-4 hours				0.02	0.98	0.00	0.08	0.99	0.00	-1.37	0.80	-0.01
4.1 – 6 hours				-0.59	0.91	0.00	-2.25	0.68	-0.01	-3.30	0.56	-0.02
6.1 + hours				**-35.62**	**<0.01**	**-0.12**	**-33.63**	**<0.01**	**-0.11**	**-35.76**	**<0.01**	**-0.12**
No response				-1.36	0.80	-0.01	-4.42	0.39	-0.02	7.29	0.21	0.04
Commute time				**-0.53**	**<0.01**	**-0.08**	**-0.59**	**<0.01**	**-0.09**	**-0.59**	**<0.01**	**-0.09**
Inactive commuters				**-8.53**	**0.03**	**-0.05**	**-9.66**	**0.02**	**-0.06**	-6.75	0.11	-0.04
School start time				**0.43**	**<0.01**	**0.09**	**0.48**	**<0.01**	**0.10**	**0.53**	**<0.01**	**0.11**
Sedentary physical activity counts /day				-0.01	0.06	-0.1	-0.01	0.13	-0.08	**-0.01**	**0.03**	**-0.12**
Moderate to vigorous physical activity counts /day				0.06	0.1	0.06	0.06	0.18	0.06	0.06	0.16	0.06
-Neighbourhood Level Sociodemographic Variables:												
Average # of children/household							**10.92**	**0.05**	**0.08**	**15.27**	**0.04**	**0.06**
% middle income families							0.00	0.07	0.04	0.00	0.24	0.03
Home location:												

	Model 1			Model 2			Model 3			Model 4		
	B	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**	**B**	**P**	**Beta**
Suburban							**16.89**	**<0.01**	**0.08**	**19.07**	**<0.01**	**0.09**
Rural							12.76	0.31	0.02	11.59	0.37	0.02
Environmental Variables:												
Average tree exposure										4.53	0.67	0.03
Proportion of time spent near:												
NDVI Areas >0.15										3.41	0.79	0.01
Park space										**13.40**	**0.01**	**0.08**
Commercial space										13.28	0.82	0.01
Institutional space										12.55	0.72	0.02
Recreational space										10.11	0.13	0.04
Residential space										15.35	0.79	0.02
Industrial space										-25.27	0.39	-0.02
Agricultural space										2.56	0.53	0.03
Road Intersections										-20.14	0.92	-0.00
Traffic Volumes >10,000										22.85	0.74	0.01
Roads										-23.72	0.1	-0.04
Sidewalks										10.04	0.45	0.02
Bike Paths										-93.04	0.09	-0.04
Multi-use pathways										28.19	0.58	0.01
Buildings										-11.32	0.26	-0.08
Water bodies										-59.82	0.62	-0.01
N		**3254**			**2609**			**2609**			**2609**	
Constant		**696.28**			**478.97**			**415.64**			**386.15**	
Adjusted R^2		**0.026**			**0.067**			**0.080**			**0.086**	

* Ethnicity base: non-visible minority; income base: <$20,000 – 39,000; screen time base: less than 2 hours; home location: urban base

Chapter 6 Discussion & Conclusion

This thesis set out to explore how certain environmental characteristics of children's neighbourhoods may have an impact on their sleep duration. A large body of literature has addressed the benefits of green space opportunity and exposure on physical and mental well-being (Almanza et al., 2012; Collins et al., 2012; Han, 2009; Kaplan & Talbot, 1983; Kaplan & Kaplan, 1989; Martensson et al., 2009; Roe & Aspinall, 2011; Schell, Cotton & Luxmoore, 2012; Soderstrom et al., 2012; Ulrich et al., 1991; Wells, 2000; Wells & Evan, 2003). What is lacking from this body of literature is knowledge concerning whether green space opportunities and exposures has an impact on children's sleep duration. Thus, this research fills a gap by examining to what extent and in what ways do green spaces and other environmental features impact children's sleep duration. This chapter is intended to provide an overview and discussion of the key findings presented within Chapters 4 and 5 and the variations based on the use of two different spatial analyses using GIS. The contributions and broad policy implications of the research findings will also be discussed along with the limitations of the research and suggestions for future directions.

6.1 Key Findings & Implications

This section will discuss some of the key findings and is divided into two sections. The first section reviews the findings related to individual and behavioural level factors, and the second section discusses the neighbourhood level sociodemographic and environmental factors. Both sections will discuss the results of measuring environmental 'opportunities' (specifically at the 1600 m buffer extent) and 'exposures'.

6.1.1 Individual and Behavioural Level Factors

As has been found in many previous studies (Dollman et al., 2004; Hasler et al., 2004; Hitze et al., 2008; Krueger & Friedman, 2009; Wolfson & Carskadon, 1998), individual and behavioural level factors were found to exert a significant influence on children's sleep duration. This was evident in this study through bivariate correlations and hierarchical multiple linear regression models. A child's age, sex, ethnicity, BMI z-score, daily amount of screen time, duration of commute to school, and school starting time remained consistently significant across all models.

Age: Bivariate analysis revealed that age was significantly negatively associated with children's sleep duration. This is consistent with previous literature which reports an inverse relationship between age and sleep duration (Dollman et al., 2004; Hitze et al., 2008; Spilsbury et al., 2004). As a controlling factor within the regression models, age remained significant across both measures of environmental assessment (opportunity and exposure). In model 4 of environmental opportunity (1600 m buffer) analysis, each year increase in age was associated with a loss in sleep of 10.57 minutes; whereas, model 4 of the exposure analysis, each year increase in age was associated with a loss of 8.04 minutes of sleep (a difference of 2.53 minutes). These findings are in line with a previous study which found that for each year increase in age children attained an average of 14 fewer minutes of sleep each night (Dollman et al., 2004). This trend is expected as typically bedtime curfews are extended with increases in age (Carskadon, 1990). The result of an extended curfew is less time available for sleep, because rise time typically remains the same as school start time stays constant between grades.

Sex: Sex became significant in the multiple regression analysis when measuring environmental opportunity at the 1600 m buffer extent and was also significant when measuring environmental exposure. Consistent with the literature (Hasler et al., 2004; Spilsbury et al., 2004) females within this sample obtain a predicted 10.81 more minutes of sleep than their male counter parts (at model 4 of the environmental exposure). Although 11 minutes is not an overly substantial amount of time, strategies for encouraging males, as well as females, to obtain healthy sleep durations should consider the promotion of earlier bed times. Promoting parental and child awareness of the value and need of adequate sleep for the child's health and wellness has the potential to contribute to healthy and adequate sleep durations for the child's age.

Ethnicity: Ethnicity was significant at the bivariate analysis and multiple regressions when measuring environmental opportunity and exposure. Children of visible minority status received less sleep than expected, while children of non-visible minority status receive more sleep than expected. When measuring environmental exposure at model 4 of the multiple linear regression, students of visible minority status receive 15 fewer minutes of sleep than their non-visible minority status counterparts. Although an association between ethnicity and sleep duration has been inconsistently reported within the literature, some studies have found similar results to this study (Hale & Do, 2007; Krueger & Friedman, 2009). Possible explanations for low amounts of sleep attained by visible minority children could be due to increased levels of life stressors among visible minority children, differing cultural practices which affect sleep duration (e.g. differing parental rules regarding bed times, or late-night cultural social practices), or parental occupational status (for instance parents working night shifts may lead to children having shorter sleep durations) (Hale & Do, 2007). However, it is not possible to confirm or reject these hypothetical explanations with the available data in this study, nor was it within the scope of the study.

BMI z-score: As in many previous studies (Bjorvatn et al., 2007; Hasler et al., 2004; Hitze et al., 2008; Krueger & Friedman, 2009; Nixon et al., 2008), a child's BMI z-score was inversely associated with sleep duration. That is, children with higher BMI z-scores typically have shorter sleep durations. Results indicate that with each increase in BMI z-score a reduction of 3.8 minutes of sleep is observed (when measuring environmental exposures and a loss of 4.8 minutes when measuring environmental opportunity at the 1600 m buffer extent). Several mechanisms may explain this trend of shorter sleep durations and higher BMI z-scores such as: reduced physical activity levels due to increased daytime tiredness (Nixon et al., 2008), obesity and short sleep durations are of related behaviours and/or parenting style (Rhee et al., 2006; Spilsbury et al., 2005), and/or a greater time awake may lead to increased caloric intake (Nixon et al., 2008). The results indicate a strong association of short sleep duration and increased BMI z-scores, even after sedentary and moderate to vigorous activity counts are adjusted for. These results further show the need for the promotion of a healthy weight status for children.

Screen Time: Aligned with previous literature (Bottino et al., 2012; Chapet et al., 2006; Hitze et al., 2008; Olds et al., 2006; Van den Bulck, 2004), an increased amount of time spent viewing screens (for example T.Vs, computer screens, or hand held video games) corresponds to shorter sleep durations. It was found that children who spend six or more hours per day in front of a screen obtain 35.76 (when measuring environmental exposure; 35.61 at the 1600 m buffer extent when measuring opportunity) fewer minutes of sleep than children who spend less than two hours in front of a screen.

Increased levels of sedentary activity (or time spent in front of a screen) are well known to be highly associated with increased levels of BMI, contributing to the obesity epidemic (Lanningham-Foster et al., 2006; Li et al., 2007). As well, children today, compared to twenty years ago, are spending a greater number of hours per day in front of screens (Wahi et al., 2011). Many intervention studies have aimed at reducing children's overall screen time; however, the results of the interventions typically show no impact (Faith et al., 2001; Harrison et al., 2006; Salmon et al., 2008; Shapiro et al., 2008; Wahi et al., 2011) with children often resisting them (Faith et al., 2001; Wahi et al., 2011). It is difficult to change or alter a child's behaviours and attitudes towards reducing their amount of screen time per day. This could be in part because a great deal of their activities and interests lie within playing video games, computer games, and watching television shows. Not only is this something children tend to do on their own, but it has also become a social norm.

Carney and colleagues (2003) advocate that sleep duration is influenced by increased arousal and in order to achieve a good nights' sleep, one needs to deactivate and quiet the mind instead of performing stressful or activating activities before bed (Manber & Carney, 2013). Carney and colleagues (2003) claim that people are "tired but wired", so in order to achieve a decent nights' sleep, individuals need to unwind. Thus, people need to take time to mentally unwind and avoid doing activities in bed, such as watching television, talking on the phone, or texting which provide interference with sleep. Therefore, a possible suggestion would be to impose curfews on screen times (for instance no screen time later than 8 pm) could help to reduce overall screen times (Olds et al., 2006).

Commute Time: It is not surprising to discover that longer duration commutes to school are associated with shorter sleep durations. This association, in line with previous research (Fox, 1996; Thompson, 1982), was found across all models. Each additional minute of commute time to school estimates a decrease in sleep duration of 0.59 minutes when measuring environmental exposure (and a decrease in sleep duration of 0.71 minutes at the 1600 m buffer extent when measuring opportunity). A child who has to commute a longer distance to school must wake up earlier than someone who has a shorter commute to school. However, these children typically do not go to sleep at an earlier time to account for the earlier rise time, thereby the duration of sleep is sacrificed. Strategies to help increase sleep duration by reducing a child's commute time to school would need to consider the distance from a child's home to their school location. These considerations would emerge from decisions made by school boards, planning policies around building density, or demographic characteristics of a neighbourhood when regarding the location of new schools and closures of existing schools. Also decisions made by parents of which school their child should attend could also have an influence on commuting distance. For instance, parents could encourage their children to attend a different school other than their local one (Bosetti, 2004). This decision could be made based on a number of reasons including, but not limited, a schools' credibility, school/school board type (e.g., public vs. private, religious vs secular, French vs English), a school offering specialized programs (e.g., art or music programs), or friend's/family members who attend a different school. This would impact the required length of commute for the child. Making school boards and parents aware of the effect that longer commute times to school have on children's sleep duration would ensure that the decisions made surrounding longer commutes would consider subsequent negative outcomes from lack of sleep.

School Starting Time: As expected, the earlier the school's starting time, the shorter the obtained sleep duration by children (which is consistent with previous studies that have found sleep durations increased significantly with a 30 minute start time delay; (Owens et al., 2010; Wolfson & Carskadon, 1998)). Children with earlier school starting times sacrifice sleep duration as their time to bed is not adjusted to accommodate an earlier rise time. According to the multiple linear regression model at the 1600 m buffer extent (when measuring opportunity), a 30 minute school start time delay results in an additional 17.4 minutes of sleep. When measuring exposure, the multiple regression estimates an additional 15.9 minutes of sleep with a 30 minute delay in school start time. These findings suggest a need to have school start times which enable children to obtain an adequate length of sleep and for parents to be mindful of adjusting curfews and bedtimes according to their child's school start time.

6.1.2 Environmental Factors

Beyond what previous studies have explored with respect to influences on children's sleep duration, this study's primary focus was to examine how children's sleep duration is influenced by their surroundings, particularly the amount of time spent in green space and other built environment types. This study employed two methods for examining the influence that the physical environment (both built and natural) has on children's health. Few built environmental features significantly impacted children's sleep duration when measuring environmental opportunities and exposure. Exposure to a greater amount of green space was hypothesized to help children obtain longer sleep durations. This hypothesis came from the notion that green space exposure has a positive association with children's physical and mental well-being including the reduction of stress (Matsuoka, 2010; Ulrich et al., 1991; Wells & Evans, 2003), and shorter sleeper durations are associated with higher levels of stress (Manber & Carney, 2013). Since the primary focus of the thesis was to examine if and to what extent environmental factors have an impact on children's sleep duration a more in-depth discussion will be presented. The format of which will first discuss the results found when measuring environmental opportunities and then will discuss the results of measuring environmental exposure.

Opportunities to Green Space: The three variables used to measure green space opportunities at the neighbourhood level were NDVI, park space, and tree count. None of these variables had a significant relationship with sleep duration at the 500 m, 800 m, and 1000 m buffer level. At the 1600 m buffer level, NDVI and park space significantly impact sleep duration. NDVI has been widely used in previous studies and increasing degrees of greenness (NDVI values of 0.1 and higher) have been found to correlate with positive health benefits to children, such as increased physical activity levels or decreased BMI (Bell et al., 2008; Grigsby-Toussaint, Chi & Fiese, 2011). NDVI, however, has not been used when measuring the effects on children's sleep duration. As demonstrated at the 1600 m buffer level, NDVI significantly impacts children's sleep duration, such that increases in the level of NDVI lengthen sleep duration. Specifically, with each increase in mean NDVI reading within a child's neighbourhood (1600 m radial buffer) children's sleep duration will increase by 8 minutes. The mean NDVI reading does not increase from the 800 m buffer to the 1600 m buffer; it remains the same with a mean NDVI of 0.17 (refer to Table 5 in Chapter 4). Therefore, a higher NDVI reading is not the reason NDVI becomes significant at the 1600 m buffer extent.

Unexpectedly, opportunity to park space had an inverse impact on sleep duration. The association is minuscule (-0.00, p=0.01) and the beta value is relatively low (-0.08), suggesting that increased opportunity to park space has a negative association with sleep duration, however the relationship is weak. The minor predicted impact that park space opportunity has on sleep duration (-0.00) leads to the belief that although a negative association was found, the impact scarcely exists. This association is interesting as it opposes what the expected outcome would be, that park space would have a positive impact on children's sleep duration. Based off these two findings, it is difficult to definitively state whether neighbourhood green space opportunities has an impact on children's sleep duration.

Opportunities to Built Environmental Features: It becomes clear after extensive review of possible environmental predictors of children's sleep that opportunity to only two built environmental predictors have an impact. At both the 1000 m and 1600 m buffer extents, living in a suburban neighbourhood (compared to an urban neighbourhood) has a significant positive impact on children's average sleep duration. This is consistent with the literature which has found that living in more urban environments is correlated with shorter sleep durations (Bottinco et al., 2010). Results from the multiple linear regression at the 1600 m buffer extent suggest that children who reside in suburban neighbourhoods tend to obtain approximately 20 additional minutes of sleep than children residing in urban neighbourhoods. Within the sample, children who reside in suburban neighbourhoods tend to go to bed at an earlier time than children who reside in urban neighbourhoods. Specifically, the mean bed time of suburban children is 9:15 pm, while the mean bedtime of urban children is 9:45 pm.

Correspondingly, the average number of children per household is significantly associated with children's sleep duration. Since there are more children per household in suburban neighbourhoods, the association found between living in a suburban neighbourhood and the average number of children per household are likely linked. A possible explanation as to why living in a suburban neighbourhood has a positive impact on children's sleep duration could include: since there are more children in the neighbourhood, a greater social life is obtained, and there are potentially more options to play or get together with a friend. Since the amount of traffic volume does not have an influence on sleep duration, the busyness of the neighbourhood or potential for noise pollution is not a likely reason for this relationship.

The second environmental predictor of sleep duration at the 1600 m buffer level is the amount of residential space, which was found to have a negative impact on children's sleep duration. However, the association is minimal and with a low beta value, estimating that with each 1000 m^2 increase in residential space sleep duration would decrease by 0 minutes ($p=0.04$). Thus, suggesting that there is no impact on sleep duration.

Exposure to Green Space: At the individual exposure level, three variables are used to measure green space: time spent exposed to NDVI values greater than 0.15

(characteristic of green areas), time spent exposed to park spaces, and the average daily tree exposure. The multiple linear regression model indicated that time spent in green areas (areas where the NDVI is greater than 0.15) and the average daily tree exposure are not significantly related to sleep duration.

The amount of time spent in park spaces was the only green space exposure variable found to have a significant relationship with sleep duration. The more time children spend in areas with park spaces, the longer their sleep duration. Because the amount of time spent in green areas (where NDVI is greater than 0.15) did not relate to children's sleep duration, the association between time spent in park space and sleep duration cannot be solely explained by exposure to green areas. While NDVI is commonly used to attain a measure of greenness, it does not capture a more qualitative measure of green. Thus, the correlation between more time spent in park spaces and sleep duration is likely obtained from other aspects of park spaces, such as the play structures or recreation facilities for physical activity. Further exploration reveals that a child's moderate to vigorous physical activity did not significantly relate to their sleep duration. This suggests that physical activity, which could potentially be taking place within park spaces, is not the reason why park space has a significant impact on children's sleep duration. Therefore, the sleep benefits of spending time within park spaces are likely due to reasons beyond infrastructure for physical activity, such as the overall aesthetic quality of the park design, the social opportunities that parks provide (i.e. socializing with friends), or the psychological benefits which they have been found to bring (Beukeboom et al., 2012; Dijkstra et al., 2006).

Much research has explored these benefits, particularly the psychological benefits, as evident within Chapter 2. Restoration from mental fatigue and a reduction of stress are two benefits found with increased park visitation (Laumann et al., 2001; Maller et al., 2008). Furthermore, natural environments have been found to be particularly restorative for individuals residing in urban neighbourhoods (Chiesura., 2004; Hansmann et al., 2007; Maller et al., 2008). As also stated within the literature review, stress plays a negative role in impacting sleep duration (Carney & Manber, 2009; Hall et al., 2004). Although this study was unable to examine the direct restorative effects of spending time within park spaces, a potential explanation of the finding would be that due to the urban living within the City of London, increased time spent within park spaces could bring about restorative and stress-reducing effects, aiding in the lengthening of sleep duration for children.

It is understandable that sleep duration is much less influenced by characteristics of the physical environment than by individual, behavioural, and social environmental circumstances in a child's life. Thus, time spent within green space does not play as large of a role as factors such as: parental rules (Meijer et al., 2001), child's sleep environment (Meijer et al., 2001), BMI level (Krueger & Friedman, 2009; Nixon et al., 2008), the amount of screen time watched per day (Hitze et ak 2008), mental health (Meijer et al., 2001), and depression (Krueger & Friedman 2009; Wolfson & Carskadon, 1998). This is especially evident when examining the adjusted R^2 values between model 1 and 2 and between models 3 and 4 of the regression tables and the beta values of each variable. After all individual and behavioural level variables were included into the model (model 2) the adjusted R^2 increased by 13.9% (in all buffer models) and 6.7% (in the hexagon surface model). After environmental predictors were added into the regression models (model 4), the adjusted R^2 only increased by 2.99%, 2.31%, 2.79%, 2.66%, and 0.6% (at the 500 m, 800 m, 1000 m, 1600 m, and hexagon surface respectively). This indicates that the individual and behavioural level variables have more of an influence than the environmental variables.

6.2 Contributions

This section will discuss the methodological and empirical contributions of this study.

6.2.1 Methodological Contributions

This thesis executed two GIS-based spatial approaches for examining the potential impact of the physical environment on children's sleep duration. A thorough investigation of both methods was undertaken, examining many possibilities with multiple environmental features. The first method explored the commonly used Euclidean buffer approach to examine the influence that opportunity to environmental features within a child's neighbourhood has on their average sleep duration. The second method utilized direct observations of GPS tracks of the children aggregated to a surface of hexagons to determine their true exposure to environmental features on a daily basis and their corresponding sleep duration that night. These two methods present two techniques used within children's geography when examining the impact of environments on children's physical health and mental well-being.

The Euclidean buffer approach has been applied to many studies to explore the impact that surrounding environmental features have on individual health (Astell-Burt et al., 2013; Kerr et al., 2006; Larsen et al., 2009). Contrary to what much previous research has done by generating a buffer around an individual's postal code centroid, census tract, or DA (Apparicio et al., 2008; Astell-Burt et al., 2013; Henry & Boscoe, 2008), this study uses more accurate geographic locations by creating a buffer around the child's actual home location. Using a child's home location to produce a buffer is more precise than other units such as postal codes, census tracks, or DAs, for example, as they are spatially aggregated units (Healy & Gilliland, 2012). When measuring opportunity, a buffer around the exact home location produces a greater sense of "what is there" than a buffer around a postal code, which, despite known locational discrepancies (Healy & Gilliland, 2012), is commonly considered as a "gold standard" in spatial epidemiological research in Canada. Postal codes often account for a large area which could potentially be out of the range of the true home – therefore, not accurately representing the child's true opportunity. Although address proxies, such as postal codes, have been widely used in previous literature, enhancements were implemented for this study with regards to exact geographic locations.

It is difficult to speculate that because an environmental feature exists within a certain area of a child's home that it has an impact on their health-related behaviours or outcomes. To go beyond the commonly used Euclidean buffer approach, GPS tracks were superimposed onto a hexagonal grid surface to measure direct *exposure* to various environmental features. This approach makes a significant contribution to methods applied within the field of geography and health research as it offers a more precise way to measure an individual's level of direct exposure to their environment. Whereas the buffer approach is used as a proxy of what individuals *could* be exposed to, the use of children's known presence at areas of interest guarantees their exposure to those areas of interest, ensuring greater validity. This method contributes to the field of geography as it offers a detailed and exact indication of what physical environmental characteristics children are exposed to on a daily basis. It is difficult to speculate that an environmental feature has an impact on a child's health only because it is within a certain area of a child's home. However, if it is known that the child is being exposed to specific environmental features, it is more sound to indicate that, if found, these environmental features do have an impact on a child's health.

From the application of both methodological approaches in this thesis, it becomes apparent that measuring a child's *opportunity* to access various environmental features through the use of a buffer technique is not a precise indication of their exposure. Thus, if the purpose is to measure the influence of various environmental features on children's health, a more direct and in-depth analysis, such as using GPS tracks on a hexagon surface, arguably provides more reliable results. Just because an environmental feature exists, for instance a park within 1600 meters of a child's home does not necessarily mean the child visits this park. Thus, it is difficult to assume or predict that just because a certain amount of park space exists around a child's home that it is impacting their behaviour or health in a certain way.

Since the children's exact travel patterns were tracked and assessed, if an association is found, it is more accurate to claim that the association is not random. With particular reference to the results found within Chapters 4 and 5, the amount of park space was not found to significantly impact children's average sleep duration at the 500 m, 800 m, or 1000 m buffer. Only at the 1600 m buffer did the amount of park space within the neighbourhood have a significant inverse relationship to children's sleep duration (-0.00, p=0.01). Yet when examining the proportion of time a child spends exposed to park spaces, a significant positive association with daily sleep duration is evident (13.40, p=0.01). Using the best possible method to explore the effect of the built environment is critical to quality research in health geography. Buffers, often of arbitrarily determined size, are not the most accurate indication of how environmental features impact health outcomes. Therefore, examining individuals' exposure is recommended in future studies.

6.2.2 Empirical Contributions

This thesis also contributes to the field of geography, children's health, and epidemiology by adding an immense amount of previously unexplored data within the City of London, Canada. Although a great deal of research has focused on children's health benefits of spending time or opportunity to green spaces (Bowler et al., 2010; Lachowycz & Jones, 2013; Norton, 2010; Wells & Evans, 2003), other built environmental features (Bluhm et al., 2004; Kluizenaar et al., 2009), and individual/social factors that impact children's sleep duration (Dollman et al., 2004; Hasler et al., 2004; Krueger & Friedman, 2009; Sadeh et al., 2003), this is the first study to attempt to identify an association between the natural and built environment and sleep duration. Although the length of sleep needed for proper growth, functioning, and health has not changed (Matricciani, Olds, & Petkov, 2012), the duration of sleep for children has been declining (Loessl et al., 2008; Smaldone et al., 2007), making this study critical to help identify natural and built environment causes of the decline.

As identified in the review of literature (Chapter 2), only one previous study to date examined how opportunity to green space would affect an individuals' sleep duration (Astell-Burt et al., 2013); however, that study explores an older adult sample (aged 45 and older), while this thesis explores the impact on children. This thesis improves upon this previous study in two major ways. First, Astell-Burt and colleagues (2013) collected the duration of sleep from a national study questionnaire where respondents answered the question: "about how many hours in each 24 h day do you usually spend sleeping" (pg. 2). Although previously used, this requires participants to recall a more general average number of hours spent sleeping. When comparing diaries and questionnaires to more objective measures of sleep (for example actigraphy) diaries tend to be more consistent with actigraphy measures than questionnaires (Werner et al., 2008). Therefore, recall bias would be much higher for questionnaires than daily diaries.

Second, Astell-Burt et al (2013) examined the percentage of green space within a 1 km buffer around the census collection districts (Australia's smallest census geographic area). This thesis measured four buffer extents, instead of one, to compare the impact of various buffer extents on results. In addition, the buffer extent was created around the child's precise home location. This, as previously stated, is superior as the home buffer would represent exactly what surrounds the home. When using any spatially aggregated area (such as the census collection district), the buffer may not represent what surrounds the participants home. Furthermore, this thesis not only measured opportunity surrounding the child's home, but also measured direct exposure to natural and built environment features. The methods applied went beyond the buffer approach and used the GPS tracks of children to explore if exposure to particular environments had an impact on daily sleep duration. This second approach in addition to the Euclidean buffer makes this study unique and a valuable contribution to the literature.

Applying the ecological framework to this thesis allowed for multiple levels of investigation (i.e. individual, behavioural, and environmental). Previous studies have focused solely on one area of focus, such as individual or environmental, whereas this thesis has expanded to capture both. Incorporating individual, behavioural, and neighbourhood level environmental features has allowed for a broader amount of knowledge to be obtained. Although additional variables could have been added for a more complete ecological approach, such as policy factors, several levels of influence were obtained.

6.3 Implications

The results of this study offer an important set of recommendations for potential "knowledge-users" to implement strategies for the betterment of children's health. Knowledge-users, a term used by the Canadian Institutes of Health Research (CIHR), is referred to an individual who can make an informed decision regarding health policies, programs or practices from information which was determined through research (2014). From this research, there are potential school and environment level implications which are described below.

6.3.1 School Level Implications

Altering an individual's behaviours or routines is often very time consuming and costly, and results in the betterment of only one individual (if successful). Alternatively, making adjustments across an entire community population is much more practical and efficient as it does not only impact one individual. Based on the findings from this study, school level implications are suggested as they would be the most practical and efficient.

Since the amount of screen time is well known to have a negative impact on sleep duration, which was also found in this sample, a reduction of screen time to help improve sleep duration and other health measures is vital. This is especially important as greater than two hours of television viewing per day has been found to be the leading risk factor for sleep disorders (Liu et al., 2007). As stated earlier, interventions have been executed with a goal to reduce screen time at the household level. These mediations would result in the altered behaviour of one individual, versus a collective population, and are often found to be unsuccessful (Wahi et al., 2011). In order to reach a larger population, schools are a suitable environment as school boards are able to implement restrictions which would be applied across several schools. Limiting the amount of videos and allotted computer time allowed in the classroom would help in a reduction of screen time and thus ultimately decrease children's overall daily screen time. Although a great deal of screen time is presumably done at home or at friend's houses, any reduction is helpful. Implemented school-level rules and restrictions are able to help aid in a reduction of overall screen time which can potentially positively influence children's sleep durations.

Another factor at the school-level found to negatively impact a child's sleep duration is school starting time. Children were found to have considerably shorter sleep duration if their school started at 8:15 am or earlier. Children who attended a school with a start time of 8:45 am, on the other hand, were found to obtain the recommended length of sleep (suggested by The Sleep Medicine and Research Center, 2013). If children are obtaining the recommended length of sleep with a school start time of 8:45 am, it would be rational to advocate that schools start no earlier than 8:45 am. This would aid in the support of a healthy night's sleep for children, which would ultimately assist in the positive health benefits that come along with a sufficient night's sleep, such as greater academic performance and concentration (Matricciani, Olds, & Petkov, 2012).

6.3.2 Environmental Implications

The amount of time children spend in park spaces was the sole environmental feature to impact sleep duration when measuring exposure. Since exposure is a more accurate representation of where children spend their time, this finding lends itself to greater emphasis for policy implications. Focusing on human ecological perspective will allow for the integration of the health needs of individuals into land-use planning and green space allocation. The *Strengthening Neighbourhood Strategy* of the City of London (2008) states that "our neighbourhoods will be environmentally and socially responsible and will have available green space, vibrant local economies and accessible amenities of daily life". As parks and recreational facilities are city-owned amenities, it is imperative to ensure equitable distribution and access throughout the city.

Upon examination of park space distribution within the sample of children from the City of London, it becomes evident that not all children have equal opportunity. For instance, 40 children (7.6%) do not have a park within 500 m of their home. This number declines to 18 children (3.4%), 9 children (1.7%), and 2 children (0.38%) not having access to a park within 800 m, 1000 m, and 1600 m from their home respectively. Creating equitable access to park spaces is essential for children as a positive association was found between time spent in park spaces and sleep duration. This thesis did not consider the impact of specific park amenities (for example sports fields or play grounds); however, previous literature has found that parks with greater amenities have found increased usage (McCormack et al., 2010). Thus, equitable distribution of parks with the most sought out amenities throughout the city is necessary.

6.4 Limitations

As with any study, there are limitations which must be considered during the interpretation of these results. For example, this study did not account for certain individual level variables, such as parental rules regarding sleep. Typically, a child's bed time is not negotiable, as parents often enforce a bed time (Morgenthaler et al., 2006). Parental rules on sleep duration are therefore an important control missing in this analysis. Unfortunately, the STEAM surveys used for this thesis did not include questions on parental rules regarding bedtime.

Concerns may also reside with subjective measures of sleep, for instance child's self-reported sleep times. A child may record his/her 'bed time' instead of the time they actually went to sleep. This situation may result in the child reporting longer sleep times than reality, because they may not be sleeping for the entire time they were in bed. Nevertheless, the reported sleep durations from this sample are consistent with previous findings (Carskadon et al., 1980; Spilsbury et al., 2004).

6.5 Moving Forward

Sleep is a very complex behaviour which is influenced by a number of multidimensional lifestyle factors (Hale & Do, 2007). Therefore, replicating this study with additional individual level factors such as parental rules is necessary. Since sleep is a complex phenomenon, it is vital to control for as many influences as possible. Additionally, using objective measures of sleep to get a more precise representation of an individuals' sleep duration would help to remove a limitation of this study. Reproducing this study with a larger population, different age groups, and in a different location would also provide an interesting comparison.

Additionally, although the application of GIS is vital for displaying and analyzing data of the objective built environment, the perceived environment should also be taken into consideration. Individuals' perception, feelings, and thoughts of their environment may have a large impact on their interactions and behaviours. Thus, taking this study a step further by incorporating children's perceptions of their neighbourhoods and daily routes would give further insights into what spaces are used and why, such as which park spaces children prefer to spend their time in and what features about the park makes it preferable over others.

6.6 Conclusion

The purpose of this thesis was to determine to what extent do green spaces and other environmental characteristics impact children's sleep duration. A child's age, ethnicity, BMI z-score, the amount of time spent in front of a screen, commute time to school, school start time, and residing in a suburban neighbourhood were all found to have an impact on children's sleep durations. Additionally, a positive association was found between children who spend more time in park spaces and sleep duration. This finding is essential as policy makers, educators, and parents can help in promoting a greater amount of time to be spent in parks for healthier sleep durations for children. Results also suggest that the commonly used buffer tool should only be used as a proxy for examining the influence of certain environmental characteristics on an individual's health. In order to more accurately determine what impacts individual's health, the use of GPS technology along with GIS should be used to capture an individual's exposure to various environmental factors.

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Appendices

Appendix A: Ethics Approval for Use of Human Participants

re-issued

Use of Human Participants - Ethics Approval Notice

Research Western

Principal Investigator: Dr. Jason Gilliland
Review Number: 17918S
Review Level: Delegated
Approved Local Adult Participants: 1200
Approved Local Minor Participants: 1200
Protocol Title: Identifying casual effects on the built environment on physical activity, diet, and obesity among children.
Department & Institution: Social Science\Geography, University of Western Ontario
Sponsor: Canadian Institutes of Health Research
Heart and Stroke Foundation of Canada

Ethics Approval Date: June 08, 2011 **Expiry Date:** August 31, 2014

Documents Reviewed & Approved & Documents Received for Information:

Document Name	Comments	Version Date
Other	Revised Healthy Neighbourhood Survey for Parents.	
Other	Revised Health Neighbourhoods Survey for Youth	
Other	Revised Activity and Travel Diary for School Days and Weekend Days.	

This is to notify you that The University of Western Ontario Research Ethics Board for Non-Medical Research Involving Human Subjects (NMREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the applicable laws and regulations of Ontario has granted approval to the above referenced revision(s) or amendment(s) on the approval date noted above.

This approval shall remain valid until the expiry date noted above assuming timely and acceptable responses to the NMREB's periodic requests for surveillance and monitoring information.

Members of the NMREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussions related to, nor vote on, such studies when they are presented to the NMREB.

The Chair of the NMREB is Dr. Riley Hinson. The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

Appendix B: Environmental Factors & Census Data Definitions

Variable	Definition	Source
Land Use:		
Commercial	Includes land or buildings for the sale of goods. This includes but is not limited to: entertainment facilities, cultural facilities, retail stores, grocery facilities, and restaurants.	Adapted from the City of London, 2012
Industrial	Includes land or buildings of industrial activities. This includes but is not limited to: warehouse establishments, storage facilities, manufacturing, and assembling facilities	Adapted from the City of London, 2012
Institutional	Includes land or buildings owned by any organization or government. This includes but is not limited to: schools, libraries, museums, and research facilities	Adapted from the City of London, 2012
Residential	Includes any land or building of residential development. This includes but is not limited to, individual homes, attached homes, and apartment structures	Adapted from the City of London, 2012
Recreational	Includes all indoor and outdoor recreation allotments intended for passive and active spaces	Adapted from the City of London, 2012
Agricultural	Includes all lands or buildings which are used for the cultivation of lands or the upbringing of livestock	Adapted from the City of London, 2012
No Land Use	Includes all roads, railways, and water bodies	Adapted from the City of London, 2012
Other Environmental Variables:		
Road Connectivity	Presents the number of road intersections	City of London, 2005
Traffic Volume	Represents the annual average daily traffic flow volume on the City of London roads.	Adapted from the City of London, 2012
Urban	Classified as any built area that was within the City of London boundaries pre 1960	Healy & Gilliland, 2012
Suburban	Classified as any built area that was within the City of London boundaries post 1960	Healy & Gilliland, 2012
Rural	Classified as any area that fall within the City of London boundary, but are outside of the urban growth boundary	Healy & Gilliland, 2012
Census Data:		
Total Population	The population density within the DA	Statistics Canada, 2006
Average number of children	The average number of children within the DA	Statistics Canada, 2006
Percentage of people aged 0-19	Percentage of people aged 0-19 within the DA	Statistics Canada, 2006
Unemployment rate	The number of people recorded as unemployed within the DA	Statistics Canada, 2006
Percentage of low-	Percentage of people of low income after	Statistics Canada,

income after tax	taxes within the DA	2006
Percentage of lone parents	Percentage of lone parents within the DA	Statistics Canada, 2006
Percentage of immigrants	Percentage of immigrants within the DA	Statistics Canada, 2006
Percentage of new immigrants	Percentage of new immigrants within the DA	Statistics Canada, 2006
Percentage of visible minority	Percentage of visible minority ('persons, other than Aboriginal peoples, who are non-Caucasian in race or non-White in colour') within the DA	Statistics Canada, 2006
Percentage of no education	Percentage of persons with no education within the DA	Statistics Canada, 2006
Percentage of rented houses	Percentage of rented homes within the DA	Statistics Canada, 2006
Percentage of owned houses	Percentage of owned homes within the DA	Statistics Canada, 2006
Median family income	The median family income within the DA	Statistics Canada, 2006
Composite index of socio-economic distress	A composite index of four variables: % unemployment, % lone parent, % no education, % low income after tax. A z-score for each of the variables is made, then added them together.	Healy & Gilliland, 2012

Appendix C: Shapiro Wilk Test for Normality

Neighbourhood Level:

		500m	800m	1000m	1600m
Variable	**Observations**	**Prob > z**	**Prob > z**	**Prob > z**	**Prob > z**
Sleep Duration	525	0	0	0	0
Demographic:					
Age	525	**0.69**	**0.69**	**0.69**	**0.69**
Grade	525	0.03	0.03	0.03	0.03
Sex	525	**0.99**	**0.99**	**0.99**	**0.99**
Ethnicity	525	0	0	0	0
Parental Income	525	0	0	0	0
Individual Level:					
BMI Z-Score	438	0	0	0	0
Total Daily Screen Time	297	0	0	0	0
Commute time	433	0	0	0	0
Inactive vs. active commuters	427	**0.97**	**0.97**	**0.97**	**0.97**
School Start Time	525	0	0	0	0
Average Activity Counts	495	0	0	0	0
Sedentary Activity Counts	495	0	0	0	0
Light – Moderate Activity Counts	495	0	0	0	0
Moderate Activity Counts	494	0	0	0	0
Vigorous Activity Counts	403	0	0	0	0
Total Quality of Life	419	0	0	0	0
Census Data:					
Average Children	525	0	0	0	0
Unemployment Rate	525	0	0	0	0
Low income after tax	525	0	0	0	0
% of lone parent	525	0	0	0	0
% of immigrants	525	0.005	0.005	0.005	0.005
% no education	525	0.0002	0.002	0.002	0.002
% of visible minority	525	0	0	0	0
% of people aged 0-19	525	0	0	0	0
% of home owners	525	0	0	0	0
% of home renters	525	0	0	0	0
% of new immigrants	525	0	0	0	0
Middle family income	525	0	0	0	0
Socio-economic distress level	525	0	0	0	0
Environmental Variables:					
Amount of Commercial Space	525	0	0	0	0
Amount of Residential	525	0	0	0	0

Space					
Amount of Recreational Space	525	0	0	0	0
Amount of Industrial Space	525	0	0	0	0
Amount of Institutional Space	525	0	0	0	0
Amount of Agricultural Space	525	0	0	0	0
Amount of No land Use	525	0	0	0	0
Maximum Traffic Volume	518	0.00001	0	0	0
Minimum Traffic Volume	518	0	0	0	0
Average Traffic Volume	518	0.00003	0.007	0.006	0
Amount of Park Space	525	0	0	0	0
Average NDVI	525	0	0	0	0
Tree Count	525	0	0	0	0
Road Connectivity	525	0	0	0	0
Urban / Suburban / Rural	525	0	0	0	0
Amount of Water Bodies	525	0	0	0	0
Amount of Bike Paths	525	0	<0.01	<0.01	<0.01
Amount of Sidewalks	525	0	0	0	0
Amount of Building Space	525	0	0	0	0
Amount of Roads	525	0	0	0	0
Amount of Multi-use Paths	525	0	0	0	0

<u>Individual Level:</u>

Variable	**Observations**	**Prob>z**
Sleep Duration	3584	0
Demographic Variables:		
Age	3584	0.001
Grade	3584	0
Sex	3584	**0.99**
Parental Income	3254	0
Ethnicity	3254	0
Individual Level:		
BMI Z-Score	2995	0
Amount of Screen Time / day	1937	0
Commute time	2786	0
Inactive vs. Active Commuters	2746	**0.93**
School Start Time	3254	0
Average Activity Counts	3100	0
Sedentary Activity Counts	3100	0

Light – Moderate Activity Counts	3100	0
Moderate Activity Counts	3096	0
Vigorous Activity Counts	2576	0
Total Quality of Life Score	2712	0
Census Data:		
Total Population	3254	0
Average number of Children	3254	0
Unemployment Rate	3254	0
Low income after Tax	3254	0
Percentage of Lone-Parents	3254	0
Percentage of Immigrants	3254	0
Percentage of Visible Minority	3254	0
Percentage of those with no education	3254	0
Percentage of those aged 0-19	3254	0
Percentage of home owners	3254	0
Percentage of home renters	3254	0
Percentage of New Immigrants	3254	0
Middle Family Income	3254	0
Socio-economic distress level	3254	0
Environmental Variables:		
Average-weighted NDVI	3121	0
Proportion of seconds spent in NDVI >0.15	3121	0
Proportion of seconds spent in low NDVI area (0.0-0.002)	3121	0
Proportion of seconds spent in medium NDVI area (0.0021-0.1)	3121	0
Proportion of seconds spent in high NDVI area (0.11-1.0)	3121	0
Proportion of Seconds spent in Park Area	3121	0
Average-weighted number of trees exposed to	3121	0
Proportion of Seconds spent in Area with >1 Tree	3121	0
Proportion of seconds spent in area with a small number of trees (0-2)	3121	0
Proportion of seconds spent in area with a medium number of trees (3-5)	3121	0
Proportion of seconds spent in area with a high number of trees (6+)	3121	0
Proportion of Seconds spent on Bike Paths	3121	0
Proportion of Seconds spent on Road Area	3121	0
Proportion of Seconds spent on Sidewalks	3121	0
Proportion of Seconds spent on multi-use paths	3121	0
Proportion of Seconds spent in Water Bodies	3121	0
Proportion of Seconds spent in Area with Buildings	3121	0

Average amount of Road Intersections Exposed to	3121	0
Proportion of Seconds spent Exposed to Traffic Volumes >10	3121	0
Proportion of Seconds spent in Agricultural Area	3121	0
Proportion of Seconds spent in Residential Area	3121	0
Proportion of Seconds spent in Recreational Area	3121	0
Proportion of Seconds spent in Commercial Area	3121	0
Proportion of Seconds spent in Institutional Area	3121	0
Proportion of Seconds spent in Industrial Area	3121	0

Appendix D: Correlations with Dependent Variable

<u>Neighbourhood Level Analysis:</u>

Bivariate Spearman Correlations with Average Sleep Duration (for continuous variables):

Variable	500 m Spearman Rho (prob >t)	800 m Spearman Rho (prob >t)	1000 m Spearman Rho (prob >t)	1600 m Spearman Rho (prob >t)
Individual Level:				
Age	**-0.16(p <0.01)**	**-0.16(p <0.01)**	**-0.16(p <0.01)**	**-0.16(p <0.01)**
Individual and Behavioural:				
BMI Z Score	**-0.09 (p =0.05)**	**-0.09 (p =0.05)**	**-0.09 (p=0.05)**	**-0.09 (p=0.05)**
Number of People in House (crowding)	0.04(p=0.32)	0.04(p=0.32)	0.04(p=0.32)	0.04(p=0.32)
Number of Siblings in Home	0.04(p=0.4)	0.04(p=0.4)	0.04(p=0.4)	0.04(p=0.4)
TV in room	0.22(p=0.71)	0.22(p=0.71)	0.22(p=0.71)	0.22(p=0.71)
School Start Time	**0.13 (p <0.01)**	**0.13 (p <0.01)**	**0.13 (p <0.01)**	**0.13 (p <0.01)**
Commute Time	**-0.16(p <0.01)**	**-0.16(p <0.01)**	**-0.16(p <0.01)**	**-0.16(p <0.01)**
Average PA (from accelerometer)	0.07(p=0.1)	0.07(p=0.1)	0.07(p=0.1)	0.07(p=0.1)
Sedentary Activity	-0.02(p=0.69)	-0.02(p=0.69)	-0.02(p=0.69)	-0.02(p=0.69)
Light Activity	-0.02(p=0.6)	-0.02(p=0.6)	-0.02(p=0.6)	-0.02(p=0.6)
Moderate Activity	0.05(p=0.19)	0.05(p=0.19)	0.05(p=0.19)	0.05(p=0.19)
Vigorous Activity	-0.07(p=0.14)	-0.07(p=0.14)	-0.07(p=0.14)	-0.07(p=0.14)
Moderate to Vigorous Activity	0.06 (p=0.19)	0.06 (p=0.19)	0.06 (p=0.19)	0.06 (p=0.19)
Total Quality of Life	-0.01(p=0.86)	-0.01 (p=0.86)	-0.01 (p=0.86)	-0.01 (p=0.86)
Neighbourhood level Sociodemographic Variables:				
Proportion of Population Density	0.02(p=0.6)	0.02(p=0.6)	0.02(p=0.6)	0.02(p=0.6)
Average number of children/household (aged 0-19 years)	**0.09(p=0.03)**	**0.09(p=0.03)**	**0.09(p=0.03)**	**0.09(p=0.03)**
Percentage of people aged 0-19	0.06(p=0.1)	0.06(p=0.1)	0.06(p=0.1)	0.06(p=0.1)
Unemployment Rate	0.03(p=0.43)	0.03(p=0.43)	0.03(p=0.43)	0.03(p=0.43)
Low income (after tax)	-0.01(p=0.73)	-0.01(p=0.73)	-0.01(p=0.73)	-0.01(p=0.73)
Percentage of lone parents	0.04(p=0.3)	0.04(p=0.3)	0.04(p=0.3)	0.04(p=0.3)
Percentage of immigrants	-0.04(p=0.32)	-0.04(p=0.32)	-0.04(p=0.32)	-0.04(p=0.32)
Percentage of new immigrants	-0.005(p=0.91)	-0.005(p=0.91)	-0.005(p=0.91)	-0.005(p=0.91)
Percentage of no education	0.03(p=0.35)	0.03(p=0.35)	0.03(p=0.35)	0.03(p=0.35)
Percentage of visible minority	0.02(p=0.6)	0.02(p=0.6)	0.02(p=0.6)	0.02(p=0.6)
Percentage of rented houses	-0.02(p=0.64)	-0.02(p=0.64)	-0.02(p=0.64)	-0.02(p=0.64)
Percentage of owned houses	0.03(p=0.46)	0.03(p=0.46)	0.03(p=0.46)	0.03(p=0.46)
Percentage of middle income families	0.06(p=0.17)	0.06(p=0.17)	0.06(p=0.17)	0.06(p=0.17)
Percentage of socio-economic distress	0.01(p=0.82)	0.01(p=0.82)	0.01(p=0.82)	0.01(p=0.82)
Environmental Variables:				
# Street Trees	0.04 (p=0.35)	0.01 (p=0.78)	0.01 (p=0.86)	-0.01 (p=0.85)

NDVI	0.01 (p=0.91)	0.01(p=0.12)	0.003(p=0.94)	0.07(p=0.11)
Amount of Commercial Space	-0.07p=0.1)	-0.06(p=0.155)	-0.06(p=0.125)	-0.05(p=0.21)
Amount of Residential Space	0.03(p=0.51)	0.01(p=0.73)	-0.001(p=0.99)	-0.02(p=0.64)
Amount of Recreational Space	-0.02(p=0.67)	0.02(p=0.61)	0.03(p=0.47)	0.05(p=0.23)
Amount of Industrial Space	-0.01(p=0.78)	0.01(p=0.8)	0.002(p=0.96)	0.05(p=0.28)
Amount of Institutional Space	**0.1(p=0.01)**	**0.13(p<0.01)**	**0.13(p<0.01)**	**0.09(p=0.04)**
Amount of Agricultural Space	-0.02(p=0.61)	-0.02(p=0.62)	0.03(p=0.45)	0.01(p=0.75)
Amount of No Land Use Space	0.02(p=0.6)	0.01(p=0.76)	0.004(p=0.92)	-0.02(p=0.64)
Amount of Park Space	-0.01(p=0.87)	-0.01(p=0.91)	-0.01(p=0.75)	-0.02(p=0.67)
Amount of Park + Rec Space	0.05(p=0.25)	0.03(p=0.46)	0.03(p=0.54)	0.05(p=0.23)
Road Connectivity	-0.01(p=0.79)	-0.01(p=0.75)	-0.01(p=0.77)	-0.01(p=0.78)
Average Traffic Density	-0.07(p=0.13)	-0.03(p=0.49)	-0.05(p=0.25)	0.003(p=0.95)
Min Traffic Density	0.02(p=0.62)	-0.01(p=0.81)	-0.001(p=0.98)	0.06(p=0.16)
Max Traffic Density	-0.05(p=0.23)	-0.02(p=0.71)	-0.07(p=0.12)	0.01(p=0.77)
Amount of Water bodies	-0.27 (p=0.53)	0.00 (p=0.93)	0.03 (p=0.45)	0.03 (p=0.44)
Amount of bike paths	-0.02 (p=0.73)	-0.02 (p=0.61)	-0.03 (p=0.45)	-0.03 (p=0.56)
Amount of sidewalks	0.04 (p=0.31)	0.05 (p=0.21)	0.03 (p=0.53)	0.02 (p=0.62)
Amount of building space	**0.1 (p=0.02)**	0.08 (p=0.07)	0.05 (p=0.24)	0.03 (p=0.51)
Amount of roads	0.02 (p=0.64)	0.03 (p=0.45)	0.00 (p=0.89)	-0.01 (p=0.83)
Amount of multi-use paths	0.01 (p=0.72)	0.01 (p=0.8)	0.00 (p=0.81)	0.00 (p=0.85)

Wilcoxon-Mann-Whitney Test with Average Sleep Duration (for categorical variables):

	Sex		**Active vs Inactive**		**Ethnicity**	
	Male	**Female**	**Active**	**Inactive**	**Non-visible minority**	**Visible minority**
Rank Sum	53677.5	84397.5	36720.5	54230.5	75586.5	62488.5
Expected	54967	83108	32879	58072	70484	67591
Z	-0.758		3.147		2.94	
Prob > z	0.449		**<0.01**		**<0.01**	

Note: only reported for one buffer size, because values will not change for each buffer

Kruskal Wallis Test with Average Sleep Duration (for categorical variables with more than two groups):

Variable:	Rank Sum	H	Prob > Z
Income ($) *4			
<20,000-39,999	12000.00	0.936	0.92
40,000-79,999	15793.00		
80,000-129,999	17740.50		
130,000+	17420.00		
Prefer not to say	75121.50		
Screen Time *4			
<2 hours	19017.50	**-15.77**	**<0.01**
2.1 - 4 hours	33401.00		
4.1 – 6 hours	21209.50		
6.1 + hours	5601.00		
No response	58846.00		
Neighbourhood Level *2			
Urban	21636.50	1.96	0.37
Suburban	114707.50		
Rural	1731.00		

Note: only reported for one buffer size, because values will not change for each buffer; * indicates degrees of freedom

Individual Level Analysis:

Bivariate Spearman's Rank Correlations with Daily Sleep Durations (for continuous variables):

Variable	Spearman Rho	Prob > t
Individual Level:		
Age	**-0.14**	**<0.01**
Individual Level and Behavioural Variables:		
BMI Z Score	**-0.04**	**0.04**
Number of People in House	0.04	0.06
Number of Siblings in Home	0.04	0.06
TV in room	-0.02	0.54
School Start Time	**0.08**	**<0.01**
Commute Time	**-0.12**	**<0.01**
Average PA (from accelerometer)	0.06	0.06
Sedentary Activity	**-0.13**	**<0.01**
Light Activity	-0.01	0.63
Moderate Activity	**0.05**	**0.01**
Vigorous Activity	-0.02	0.38
Moderate to vigorous activity	**0.05**	**0.01**
Total Quality of Life	-0.02	0.23
Neighbourhood Level Sociodemographic Variables:		
Proportion of population density	-0.01	0.56
Average number of children/household (aged 0-19 years)	**0.05**	**<0.01**
Percentage of people aged 0-19	**0.04**	**0.03**
Unemployment rate	0.00	0.98
Low income (after tax)	-0.01	0.50
Percentage of lone parent	0.02	0.31
Percentage of immigrants	-0.02	0.28
Percentage of new immigrants	-0.00	0.99
Percentage of no education	0.02	0.38
Percentage of visible minority	0.02	0.38
Percentage of rented houses	-0.03	0.15
Percentage of owned houses	0.03	0.08
Percentage of middle income families	**0.04**	**0.04**
Percentage of socio-economic distress	-0.00	0.83
Environmental Variables:		
Average-weighted NDVI	**0.07**	**<0.01**
Proportion of seconds spent in NDVI >0.15	0.02	0.3
Proportion of seconds spent in area of low NDVI (0.0-0.002)	**-0.04**	**0.02**
Proportion of seconds spent in area of medium NDVI (0.0021-0.1)	-0.01	0.61
Proportion of seconds spent in area of high NDVI (0.11-1.0)	**0.05**	**0.01**

Proportion of seconds spent in park area	0.02	0.28
Average-weighted number of trees exposed to daily	0.01	0.78
Proportion of seconds spent in area with >1 tree	**-0.04**	**0.05**
Proportion of seconds spent in area with a small number of trees (0-2)	0.03	0.06
Proportion of seconds spent in area with a medium number of trees (3-5)	**-0.06**	**<0.01**
Proportion of seconds spent in an area with a large number of trees (6+)	-0.03	0.07
Proportion of seconds spent on bike paths	**-0.09**	**<0.01**
Proportion of seconds spent on road area	**-0.07**	**<0.01**
Proportion of seconds spent on sidewalks	**-0.05**	**<0.01**
Proportion of seconds spent on multi-use paths	**-0.07**	**<0.01**
Proportion of seconds spent in water bodies	**-0.08**	**<0.01**
Proportion of seconds spent in hexagon with buildings	**0.04**	**0.04**
Average amount of road intersections exposed to	-0.03	0.11
Proportion of seconds spent exposed to traffic volumes >10,000	**-0.08**	**<0.01**
Proportion of seconds spent in agricultural area	**-0.05**	**<0.01**
Proportion of seconds spent in residential area	0.004	0.85
Proportion of seconds spent in recreational area	-0.02	0.23
Proportion of seconds spent in commercial area	**-0.08**	**<0.01**
Proportion of seconds spent in institutional area	**0.09**	**<0.01**
Proportion of seconds spent in industrial area	**-0.09**	**<0.01**

Wilcoxon-Mann-Whitney Test with Daily Sleep Duration (for categorical variables):

	Sex		**Active vs Inactive**		**Ethnicity**	
	Male	**Female**	**Active**	**Inactive**	**Non-visible minority**	**Visible minority**
Rank Sum	1604631	2706885	1287748.5	2264696.5	3233383	3097440
Expected	1649125.5	2662390.5	1193035	2359410	3190937	3326880
Z	-1.141		5.053		4.396	
Prob > z	0.25		**<0.01**		**<0.01**	

Kruskal Wallis Test with Average Sleep Duration (for categorical variables with more than two groups):

Variable:	Rank Sum	H	Prob > Z
Income ($) *4			
<20,000-39,999	412727.50	4.32	0.36
40,000-79,999	574308.00		
80,000-129,999	633627.50		
130,000+	633525.50		
Prefer not to say	2.60e+06		
Screen Time *4			
<2 hours	407948.50	**-35.02**	**<0.01**
2.1 - 4 hours	1.19e+06		
4.1 – 6 hours	838796.00		
6.1 + hours	422329.00		
No response	2.00e+06		
Neighbourhood *2			
Urban	834418.50	**8.107**	**0.02**
Suburban	4.39e+06		
Rural	76047.00		

* indicates degrees of freedom

Curriculum Vitae

Education:

M.A. in Geography — Western University (London, ON)
Fall 2012 - September 2014 (Expected)

B.A. in Geography & Environmental Science Honours — McMaster University (Hamilton, ON)
Fall 2007 - April 2012

Work Experience:

Research Associate — September 2012 – August 2014
Human Environments Analysis Laboratory (HEAL)

Teaching Assistant — September 2012 – May 2014
Western University

Teaching Assistant — January 2012 – April 2012
McMaster University

Awards and Scholarships:

The University of Western Ontario Graduate Scholarship	2012-2014
The Environmental Issues Prize	2012
The University Senate Scholarship for overall academic excellence	2010
Dean’s Honour List	2010-2011