ASSESSING THE INFLUENCE OF ENVIRONMENTAL CONTEXT ON RESPONSES TO NOISE EXPOSURE IN THE CITY OF TORONTO

By

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Abstract

This thesis examines individual and community noise perception of environmental noise in three neighbourhoods in the city of Toronto. The significance of this research is based on a relative absence of literature on how noise sensitivity and annoyance are affected by non-acoustic factors such as the built environment, demographic, and socio-economic factors. Data from a neighbourhood noise survey (n=552) were combined with spatial data on exposures to noise. Bivariate analysis, multivariate regression, and classification and regression tree (CART) analysis were used. The results showed that participants in Downtown and Don Valley have similar noise responses (64% and 67% high annoyance) despite differences in noise exposure (LAeq 24h: 66.8 and 59.3). Estimation of Community Tolerance Levels (CTL) confirmed that participants exposed to lower sound levels have a lower tolerance of noise. Further results showed that a neighbourhood with high socioeconomic status and access to green space, and relatively low night time noise levels were still two times more likely to report high annoyance, compared with neighbourhood with moderate socio-economic status and lower access to green space. The results suggest that environmental context influences expectations and sensitivity to noise.

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1. CHAPTER ONE

1.1. Overview

This thesis is a manuscript type of thesis made up of one paper currently being prepared for publication. While the paper is co-authored with my thesis supervisor, Dr. Tor Oiamo, as the first author I conducted the majority of research, literature review, survey data collection, data analysis, and writing. The co-author Dr. Tor Oiamo provided guidelines on revising the manuscript, and conducted the monitoring and modeling for noise.

The thesis consists of three chapters including this introductory chapter. Chapter One provides the theoretical frameworks of environmental health geography and the soundscape approach, drawing on pathways between exposure, perception, and stress responses in the environment. Chapter Two seeks to understand how these pathways play a role in noise responses at the neighbourhood scale. Specifically, how neighbourhood context, including physical environment and human characteristics, can influence individual's noise perception. In doing so, the chapter proposes and tests a multivariate statistical model for the relationship between noise annoyance, noise sensitivity, and noise exposure. Chapter Three presents broad conclusions and the potential applications of the thesis.

Chapter One provides the overview of relevant theoretical perspectives on important considerations in the study of embodying human perception and understanding its role within the relationship with the environment. A discussion of conceptual and contextual understanding of space and place and their role in human behaviour is presented. An introduction of ambient environmental stressors, specifically noise pollution, followed by overview of regulations in response to the noise pollution challenges are analysed. Finally, the objectives of the thesis are provided in context of research needed to address these challenges.

1.2. Environment, human perception, and stress

The interface of the environment, the human body and mind has been much theorized in social science and medicine (Last, 1987; Kearns, 1993; Parr, 2010). The human senses of a space define the environment (Tuan, 1979). For this reason, certain odour, sound, and visual settings can arouse positive or negative perceptions of a space. Moreover, human's perception of a space goes boyend human senses into psychological responses; a space (defined as an area, land) becomes a place when human emotion and attachment is involved (Tuan, 1979; Parr, 2003). Experiencing space for a first time, is a learning process, where senses stimulate first impressions and feelings. Having many experiences in a space transforms the space into place, and that creates a meaning. The place now evokes memories and sentiments. For instance, walking the street to a childhood home inevitably will bring emotions and memories of the past. However, the same street will have no meaning, and will evoke no emotions to someone else. The way humans perceive places differs between individuals. Consequently, experiences of place will differ among people. Similarly, places reflect the human sensations (Tuan, 1979). Certain physical environment can evoke fear, stress, discomfort, and illness (Evans & Cohen, 1982; Slovic, 1987; Rosenberg, 1988; Kearns, 1993). This relational perspective of place and people is the central area of study in health geography and the soundscape approach. Place-to-place variations and conditions in the environment are influential to human health and wellbeing (Last, 1987). Recognizing that the environment has effects on human health through psychological and physiological pathways is theoretically grounded by the research field of health geography and soundscapes. This relational concept provides fundamental knowledge and serve as the base of developing the understanding of environmental stress framework.

Environmental stress can be defined as an individual response typically following a disruption of ongoing behaviour and posing a predicament of personal ability to cope with environmental burdens (Evans & Cohen, 1982). Evens and Cohen (1982) identified four categories of stressors: cataclysmic events, stressful life events, daily hassles, and ambient stressors. Cataclysmic events, such as an earthquake, a volcano eruption, and a tsunami require major adaptive responses, but they might be supported by a sense of common social advocacy from all of the affected. Stressful life events, such as change in family or/and economic status, require personal or/and social adaptive responses. Daily hassles, which are short timeline events, such as a loud party or argument in the family require coping with individuals' irritation. Ambient stressors are global, not individual, stressors that integrate in the background of the environment, such as air-pollution, noise pollution, and crowding (Evans and Cohen 1982; Campbell, 1983). These ambient stressors are chronic, and intractable to individuals' effort to change them; they can negatively affect health even among individuals who are not consciously aware of their existence (Evans and Cohen 1982; Campbell, 1983).

Stress has a direct physiological effects on human's health that is related to malfunction of the brain and the cells of the body. Stress releases the three major stress hormones cortisol, epinephrine, and norepinephrine into the blood system causing high blood pressure, related to malfunctioning of blood vessels and cholesterol plaque build-up; among other factors predisposing cardiovascular disease (Evans & Cohen, 1982; Persson & Zakrisson, 2016). Furthermore, stress has direct psychological effects on health and wellbeing, causing negative cognitive responses (difficulty concentrating, constant worry), negative emotional responses (frustration, irritation), and negative behaviour responses (decreased social activities) (Evans & Cohen, 1982; Persson & Zakrisson, 2016). The responses to the psychological effects of ambient stressors are strongly individual-based (Lazarus, 1966; Oiamo, 2014). These responses include a primary appraisal, "dependent on the individuals' interpretation of an ambient stressor"; and secondary appraisal, dependent on the ability to cope with the stressor (Oiamo, 2014, p.6). As such, the interpretation of environmental stress and coping are influenced by the stressor itself, the individual itself, and from socio-cultural interactions (Slovic, 1987; Oiamo, 2014).

The field of study concerned with risk perception investigates the experience of individuals and communities that are exposed to pollution or other hazardous technological installations, and their response to the associated risk (Bickerstaff &

Simmons, 2009). The analysis of risk perception and responses are formed through individuals' experiences but also through "cultural assumption across social groups" that can influence individuals' risk perspectives and actions (Bickerstaff & Simmons, 2009, p.864). Risk perception and responses are beyond the scope of this thesis, but the concept warrants attention because of its relevance to the influence of social networks and geo-political context of individual's perception of the environment and in particular to the perception of noise. For example, Fields (1993) suggests that certain attitudes are related with noise responses, such as fear of danger from the noise source (Fields, 1993) . Moreover, noise sensitivity and noise annoyance might be influenced by perceptions of risk associated with noise source (Job, 1999; Miedema & Vos, 2003; Oiamo, Luginaah, & Baxter, 2015).

1.3. Neighbourhoods and soundscape

There is a growing body of literature showing the relationship between social networks and health outcomes (Coleman, 2000; Cattell, 2001; Veenstra et al., 2005). Social networks are sources of social support, which could be tangible in a monetary form, informative in an advice form, and general support coming from interpersonal bonding. This definition of social support forms the concept of social capital. Social capital is social structure, including social support, business networks, and interpersonal trust and safety, that forms a sense of community that facilitates shared benefits (Veenstra et al., 2005; Gatrell & Elliott, 2009). These aspects of social capital are shown to influence community health, and as such they appear as part of the neighbourhood context.

Various research shows that disadvantaged neighbourhoods, those with less green space, social isolation, and limited socio-economic strata are associated with poor health (Kawachi et. al, 1997; Forrest & Kearns, 2001; Macintyre, Ellaway, & Cummins, 2002). For example, a study by Wilson, et al. (2004) showed that citizens with lower socio-economic status and perceived unpleasant environments (lack of green space, and proximity to industrial facilities) on a neighbourhood scale in Hamilton, Ontario, Canada were 1.5 times more likely to report chronic health conditions and poor emotional health (Wilson et al., 2004). Conversely, neighbourhoods with greater social capital, are often the ones with greater access to green space, which can operate as therapeutic landscapes providing physical, mental, and spiritual healing and wellbeing (Velarde, Fry, & Tveit, 2007; Cattell et al., 2008; Gatrell & Elliott, 2009). Furthermore, neighbourhoods with greater social capital can provide greater access to health care and therefore indirectly promote better health (Veenstra et al., 2005; Gatrell & Elliott, 2009). Overall, advantaged neighbourhoods can facilitate greater access to economic (jobs, housing), environment (mobility, accessibility), and natural (green space) resources (Putnam, Leonardi, & Nanetti, 1993; Veenstra et al., 2005). This comes from the fact that higher social capital provides power that gives the community leverage to make changes. These changes can be related with protecting the community from local environmental hazards, maintaining a good environment, assuring safety and support of the community, and even influencing policy changes. For example, stronger social networks in some neighbourhoods enable greater public participation in urban planning and environmental decision making, which increases the chances of a public concern to be added to the government agenda and therefore to initiate policy change (Stone, 1989; Forrest & Kearns, 2001). Thus, the role of neighbourhoods is important in developing knowledge of the relationship between human perception and environment, considering contextual factors (environmental characteristics), compositional factors (individuals' characteristics), and collective factors (social capital) (Kawachi *et. al*, 1997; Forrest & Kearns, 2001; Gatrell & Elliott, 2009).

In regards to noise perception, neighbourhoods are also seen as an important factor (Klæboe et al., 2005; Gatrell & Elliott, 2009; Oiamo et al. 2015). The influence of environmental context on human reaction to noise is central to the soundscape perspective. The soundscape approach represents a departure from a traditional noise research, where a human is a passive receiver. In a traditional noise research, the metrics of sound pressure levels are used to define loudness, and further used to develop noise control methods. However, previous studies showed that undesirable sounds influence negative sound perception that can lead to annoyance among citizens, which can detract from their quality of life (Dratva et al., 2010; Schafer, 1993; Shepherd, Welch, Dirks, and McBride, 2013; Yang and Kang, 2005; Yu and Kang, 2010). These findings showed the need to deconstruct sonic environment in order to improve and design better one. Therefore, human judgment is important in order to define desirable and non-desirable sounds in urban areas. For this reason, the soundscape approach emphasize that the sonic environment can be truly understood through peoples' perceptions. The soundscape is an urban landscape that has a full range of sounds, at a given time, where the human perception of these sounds contributes to the characteristics of the landscape (Palmer, 2008; Liu *et al.*, 2014a).

Thus, human perception is key to the urban acoustic environment. Noise exposure is just one of the many influences on sound perception (Liu *et al.,* 2014b; Oiamo *et al.,* 2015). Because humans are multisensorial, their perception of sound can be influenced by other senses such as odor and vision (Viollon, Lavandier, & Drake, 2002; Oiamo et al., 2015). Therefore, understanding how people perceive sound mentally would give a better understanding of a soundscape. Another key element of the soundscape is the landscape itself with all its characteristics: natural and built environment, all visual elements, and the function of the place (Murphy and King, 2014). Research shows that environments with more urban and concrete visual settings lead to stress and the perception of unpleasant sounds (Viollon *et al.*, 2002). In contrast, there is a link between natural environments (e.g. vegetation) and perceived sounds, where the presence of vegetation decreases the level of annoyance, regardless of the level of sounds (Irvine *et al.*, 2009). To the extent of the current knowledge, there is no study that shows influence of neighbourhood on expectations about the sonic environment.

Schafer, (1993), Schomer *et al*. (2012), Liu *et al.* (2013), and Thorne & Shepherd, (2013) are among the proponents of soundscape research perspective and identify the soundscape approach as an important step towards a better understanding of individuals' noise perception. Moreover, they argue that the soundscape perspective's psychoacoustic continuum can contribute to reducing the health risks from environmental noise and enhance quality of life and wellbeing through the promotion of better sounds in urban areas.

1.4. Noise, noise assessment, and regulations of noise

Noise pollution in urban areas has been recognized as a problem since the 1950s when Jane Jacobs argued that noise from locomotives, buses, carriages, and private vehicles took away quiet areas that are vital and socially important (Jacobs, 1961). Furthermore, in The Tragedy of the Commons, Garret Hardin (1968) pointed out that noise from shops and advertisements is negatively interacts with citizens' right to quietness, which he pointed out is a pleasure and a part of the commons, that everyone shares (Hardin, 1968). In the same time period, noise studies produced by jet engineers led to the development of noise-controlling legislation, such as the *US Noise Control Act (1972).* The first city in Canada to attempt to enforce a noise bylaw was Ottawa in 1969 (The Ottawa Journal, July 30, 1969). However, it was not until the amendment of the *Environmental Protection Act* in 1975 by the Canadian Ministry of Environment that municipalities in Canada were given legislative authority to adopt noise by-laws. This lead to the publication of "Guidelines for Noise Control in Land Use Planning" in 1978, published by Ontario Ministry of Environment (MOE). The recommended indoor noise threshold was set to 40 dB(A) for bedrooms and 45 dB(A) for living rooms, based on equivalent average sound levels (L_{eq}). Further amendment in 1997 added an outdoor noise threshold of 55 dB(A) during all hours. The last amendment of MOE guidelines in 2013 (NPC-300) provided further details on assessment methods, however it kept the recommended noise thresholds.

Previous policies, including the WHO Guidelines for Community Noise (1992), dealt predominantly with exposure to loud sounds and occupational noise. However, today the environmental noise problem is more complex due to new technology and urban growth. Substantial emerging research shows that low-frequency sounds, frequently induced sounds, and chronic exposure to noise are not conducive to citizens' well-being (Schomer et al., 2012; Murphy & King, 2014; Mesihovic, Rindel, & Milford, 2016). Therefore, many major cities are in the process of updating their noise regulations in order to achieve quality of life for the citizens and assure the quiet environment and peaceful sleep.

The existing Noise bylaw in Toronto, *Toronto Municipal Code, Chapter 591, Noise* is currently under review. It was created in 1995 in response to noise complaints from citizens of Toronto. However, the last review was in 2003 and the current bylaw still refers to publications from 1995. While this may pose some problems in regard to outdated, vague, and unclearly written policy, the current review focus should be on addressing the current environmental problems and setting long-term noise reduction targets.

1.5. Goals and objectives

The overarching objectives of this proposed study are to advance the understanding of how neighborhood context influences individuals' noise perception. Therefore, the main research hypothesis is that the neighborhood context, which include individual context (e.g. sensitivity, personal characteristics) and environmental context, influences community tolerance levels and perception of noise.

Three research questions test the research hypothesis:

1) Are there differences in noise responses between neighbourhoods in Toronto?
2) What is the relationship between noise annoyance and noise exposure? Do Community Tolerance Levels demonstrate differences in this relationship in the three study neighbourhoods?
3) Can specific predictors of neighbourhood context be identified to predict differences in individual responses to noise?

The first question tests if there are differences between the three neighbourhoods. The hypothesis is that there will be differences because the three neighbourhoods are different in their noise exposures and built environment. As it was found in Oiamo *et al.* (2015) research there are significant differences in noise sensitivity at a neighborhood-level in Windsor, Canada. Similar results were expected in the three neighborhoods in the City of Toronto.

The second question tests if only noise exposure explains the noise annoyance dose-response. The hypothesis is that not only noise exposure affects the noise annoyance responses but other factors have an influence as well (i.e., demographic, socio-economic, and physical environment). This hypothesis is based on previous research on the influence of physical environments on noise responses (Silva *et al*. 2014, Lam *et al*. 2013, Guedes *et al.* 2011; Viollon, Lavandier, and Drake, 2002). Furthermore, defining Community Tolerance Level (CTL), where the CTL curve is the best fit to the collected data from the Neighbourhood Noise Survey; and residents of the three neighbourhoods in the city of Toronto self-reported high level of annoyance. The hypothesis is that the relationship between noise annoyance and noise exposure will influence CTLs. This hypothesis is based on previous research conducted by Fidell *et al.* (2011) and Schomer *et al*. (2012).

The third question tests if noise annoyance responses are affected by individual and environmental context. The hypothesis is that demographic, socio-economic, and physical environment will have an effect on noise annoyance responses. This hypothesis is based on previous research on influence of physical environment on noise responses (Silva *et al.* 2014, Lam *et al.* 2013, Guedes *et al.* 2011; Viollon, Lavandier, and Drake, 2002).

2. CHAPTER TWO – Research Manuscript

Abstract

Environmental noise is an increasing challenge worldwide. Growing urban populations, conflicting land uses, and more traffic exaggerate existing noise pollution in urban centres. Toronto is one of the cities facing challenges in tackling environmental noise. The significance of this research is based on a relative absence of literature on how noise sensitivity and annoyance are affected by non-acoustic factors, such as the built environment, demographic, and socio-economic factors. Data from a neighbourhood noise survey (n=552) in 2017 was combined with spatial data on exposures to noise. Bivariate analysis, multivariate regression, and Community Tolerance Levels (CTL) were used for the quantitative analyses. The results indicate socioeconomic and physical environment factors influence the noise annoyance responses and the CTLs, which support the notion that neighbourhood contexts influence noise perception. This study found that residents in a neighborhood with high socioeconomic status and access to green space, and relatively low night time noise levels, were still two times more likely to report high annoyance when evaluating the neighbourhood soundscape, compared to neighbourhood with moderate socio-economic status and lower access to green space. The findings suggest that high environmental quality might be related with high expectations. For future research on noise perception the results warrant explicit consideration of shared neighbourhood perceptions of noise and environmental expectations.

2.1. Introduction

Environmental noise is an increasing challenge worldwide. In 2012 it was estimated that 125 million European citizens are exposed to levels of road traffic noise above those recommended by the World Health Organization's limits (50dB(A) nighttime; 55dB(A) daytime) (European Environment Agency, 2016). In Australia, 40% are exposed to high levels of traffic noise (Stewart, 2011). In New York City noise pollution is considered a foremost quality of life problem (Hammer *et al*. 2014). In Toronto, noise complaints increased by 312% for the period 2009-2015 (Municipal Licensing and Standards, 2015). Environmental noise and bad air quality are the most significant environmental health threats in Europe (European Environment Agency, 2016).

Research shows that involuntary exposure to ambient noise has direct effects such as hearing impairment (Rabinowitz, 2000), noise annoyance and sleep disturbance *(Dratva et al.,* 2010*;* Kluizenaar *et al.*, 2011, *Kim et al.*, 2012;). Other research shows indirect effects of noise, such as increases in stress hormones and associated effects on the cardiovascular system (Babisch, *et al.* 2001; Recio *et al*., 2016); disturbed cognitive processes in students (Lercher *et al*. 2003), reduced performance abilities, and depression (Tafalla and Evans, 1997). Laboratory-based experimental research on the effects of sounds on humans confirm the relationship between neuroendocrine responses and auditory stimulations (Bluhm, 2007). Although, biomedical research on noise and its effect on human health have contributed to the current knowledge of these adverse health effects, there is a limited understanding of individual's self-experience (Engel, 1989; Abelson, Rupel, & Pincus, 2008). Population based studies show results that reflect laboratory research findings, but results can be difficult to interpret within a biomedical model of health. Biomedical samples are used to test a primary cause of disorder/illness/disease, but this method has a limitation in explaining mental health (Engel, 1989; Abelson, Rupel *& Pincus.*, 2008). The biomedical models include mental diseases only when they can be addressed in a clinical way. However, there are certain mental stressors that do not fall into clinical diagnoses. For instance, perception of sound effects humans in physiological, psychological, cognitive, and behavioral ways, which simultaneously makes the biomedical models of research incapable to capture the full extent and impact of noise responses. Therefore, there is a gap in the complete understanding of individuals' noise perception based on biomedical research.

Noise annoyance is an indicator of response to noise exposure and it can serve as a moderator of adverse health outcomes (Oiamo *et al.*, 2015). Noise annoyance is associated with disturbance, unpleasantness, and anger (Babisch *et al.*, 2012; Genuit and Fiebig, 2006). It can lead to aggressive behavior, fatigue, and overall to various negative emotions (Ouis, 2002). Equivalent sound pressure levels averaged over different periods of time has been largely used as a sole predictor variable of annoyance. However, this method is not considered entirely satisfactory because annoyance has long been understood to be strongly subjective factor (Fidell *et al.*, 2011). Several studies have focused on non-acoustical variables, including socio-economic and attitude factors that may influence noise annoyance (Fields, 1993; Fyhri and Klaeboe, 2006). Other studies show the interaction of built form and urban noise (Guedes, Bertoli, and Zannin, 2011; Lam *et al.*, 2013; Silva *et al*., 2014; Tang and Wang, 2007). Built form and the related architectural design, arrangement, existence of open spaces, absorption characteristics of building materials, and shape have been studied to influence noise perception. For example, Silva et al. (2014) tested 10 types of urban built forms and found out that the built forms that have interior of the block (closed housing blocks) correspond to lower noise levels reducing interior noise exposure (quiet façade). The findings of Silva et al. (2014) strengthen the importance of access to a quiet façade in reducing noise annoyance.

Research by Tang and Wang, 2007 confirmed that historic urban forms with their characteristics such as narrow streets, complex road networks, medium building height, and numerous intersections reduce traffic volume which leads to lower traffic noise levels. In contrast, cities built after the introduction of cars and their characteristics of more space dedicated to roads and high rise buildings produce higher levels of traffic noise (Tang and Wang, 2007). Traffic noise is associated with a stressful sound environment and related to annoyance, and conversely, a human sound presence like footsteps and voices, and natural sounds (e.g. bird song) are associated with relaxing, positive sound environment (Viollon, *et al.,* 2002; Raimbault & Dubois, 2005). More recent research by Sanchez et al. (2016) reported that geometrical street design can reduce the street canyon effect and therefore, reduce negative noise perceptions of pedestrians and other affected population (Sanchez, *et al.*, 2016). Furthermore, vegetation has been studied to be effective in absorbing and scattering sounds

(Huddart, 1992; Thompson, C. *et al.*, 2016). Green space and vegetation are associated with reducing negative perception of noise, and therefore reducing the noise annoyance (Antonio González-Oreja et al., 2010; Irvine et al., 2009).

Viollon *et al.* (2002), reported that vision is an important indicator of sound perception. Urban green space and related sounds (e.g. bird song, running water from fountain, children playing) are associated with relaxing soundscape (Viollon et al., 2002; Raimbault & Dubois, 2005). Furthermore, there is extensive literature showing the importance of green space and vegetation as therapeutic landscapes that have been proven to contribute to physical and mental health and wellbeing (Agyemang *et al*., 2007; Gatrell & Elliott, 2009; Gatrell, 2013; Keniger *et al.*, 2013; Thompson *et al.*, 2016). A recent report from WHO on urban green spaces and health shows the various pathways of the relationship of urban green space and health and well-being, such as anthropogenic noise buffering, relaxation, restoration, reduced cardiovascular morbidity, and more (Thompson *et al.*, 2016). With such a profound effect on human health it can be expected that green space and vegetation are factors that influence noise annoyance.

There is a long legacy of research trying to quantify environmental noise levels and individuals' noise perception (Schultz, 1978; Fidell *et al.*, 1988; Miedema & Vos, 1998; Miedema & Oudshoorn, 2001). Despite this, the use of different metrics and methods for noise exposures, inconsistent evaluation of measurements of noise annoyance, and lack of control of certain factors in assessing noise annoyance suggest that more research is needed. Previous research investigates the relationship between noise exposure and noise annoyance, but it is not clear how sensitivity, which is an important predictor for annoyance, and annoyance itself, are affected by non-acoustic factors. (Schomer *et al.,* 2012; Pierre and Maguire, 2004; Taraldsen, Gelderblom, and Gjestland, 2016). Schomer *et al.* (2012) show that different communities exposed to the same level of noise can exhibit significant variation in terms of their response to the noise as measured by annoyance (Schomer *et al.,* 2012). This suggests that the environment can influences noise responses and that the particular characteristics of noise (e.g. tone, temporal structure, and spectrum, etc.), individual characteristics (e.g. health, age, noise sensitivity), and socio-economic factors may be important (Genuit & Fiebig, 2006; Oiamo *et al.*, 2015; Schomer *et al.*, 2012). For this reason, this study uses a novel analytical approach to determine the influence of neighbourhood context, which include individual context and environment context, on citizens' noise perception. Recursion partitioning and regression modeling were utilized to examine the demographic, socio-economic, and health characteristics that contribute to the noise annoyance among citizens of Toronto. Furthermore, Community Tolerance Level (CTL) analyses were performed in order to illustrate the group sensitivity to noise in the city of Toronto.

2.2. Methods

2.2.1. Study area

Toronto is located along Lake Ontario in the southern part of Ontario, the most populous province in Canada. The city covers approximately 630.21 km^2 and has a population of 2.7 million (Statistics Canada, 2016). Toronto is the capital of Ontario and it is ranked the largest city in Canada by population. As such it is a global city, considered as one of the most multicultural and cosmopolitan cities worldwide. Toronto is characterized by urban form commonly observed in other large cities throughout North America with high-rise buildings and high density in the downtown core and variety of residential builds outside of the downtown: condominiums, low-rise buildings, townhouses, semi-detached, and detached houses. Throughout the city there are major traffic corridors that provide access to multiple highways.

Questionnaire data was collected in three study sites in the city of Toronto: Trinity-Bellwoods, Church-Yonge and Bay Corridor (referred to as Downtown), Banbury - Don Mills (referred to as Don Valley) (Figure 1). The three sites are neighbourhoods in the city of Toronto that represent the diversity of built forms and environments that the population of Toronto is exposed to. In other words, neighbourhoods in this study represent distinct residential areas of the city where people live, work, and interact with each other and with the environment. There are also differences in the socio-economic status in the three neighbourhoods (Wellbeing Toronto, 2016). However, the three neighbourhoods were targeted because of the inherently different built forms. Maps of the individual neighborhoods can be seen in Appendix A.

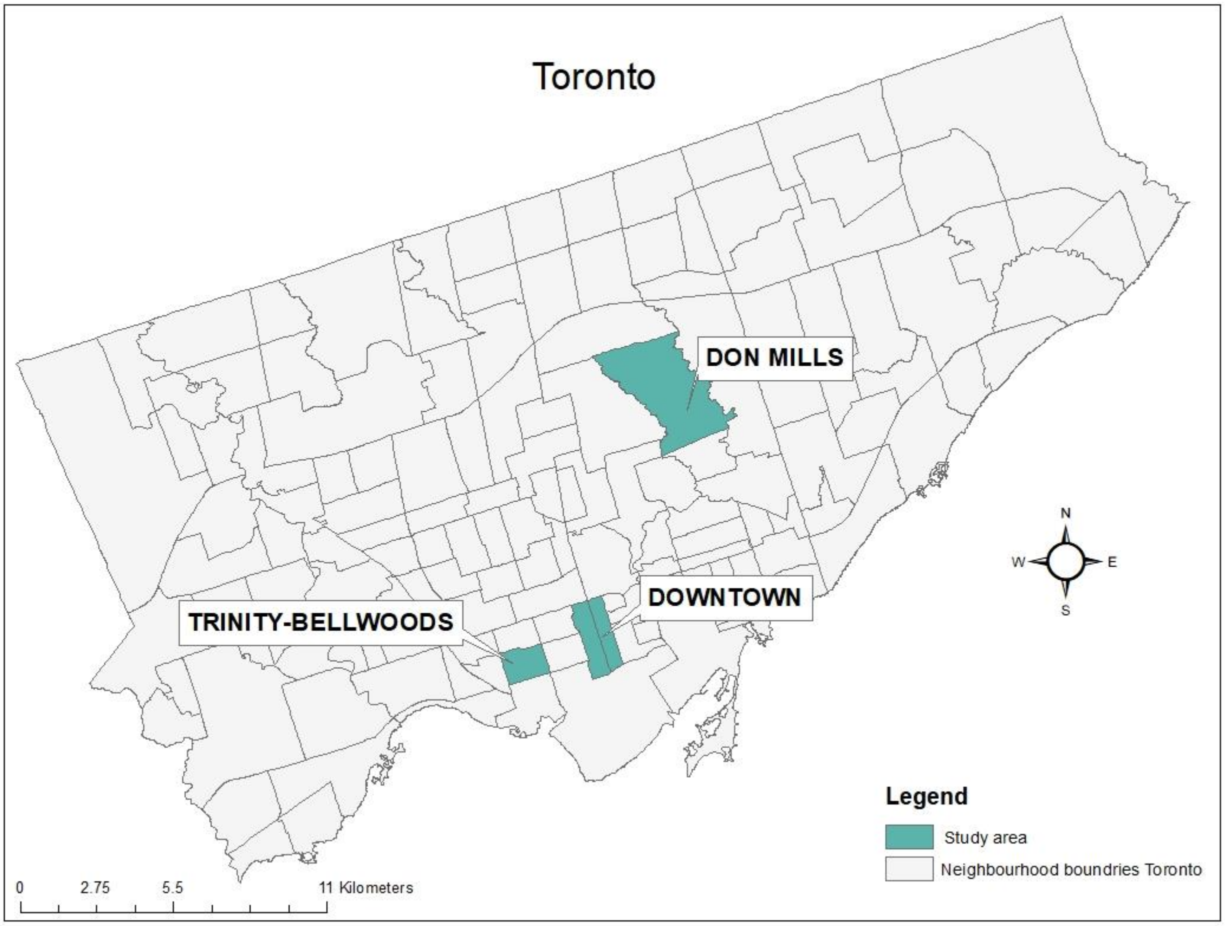


Figure 1. Sampling Area in Toronto

The Trinity-Bellwoods neighbourhood is located in the south west part of the city of Toronto. It is an inner-city neighbourhood that represents a community with middle density and middle income status. The majority of the residents live in semi-detached houses. The three main streets that cross horizontally through the neighbourhood represent stretches of restaurants, bars, shops, and other businesses, which makes the neighbourhood lively. There is access to multiple transportation systems such as streetcars, subways, buses, and bike paths located within the neighbourhood. Trinity-Bellwoods Park, which is a popular public park, is also situated in this neighbourhood. During the summer the park is often set for multiple cultural and music events.

The Downtown neighbourhood (Church-Yonge and Bay Corridor) is the main central business district in the city of Toronto. This neighborhood represents a community with mixed residential and commercial buildings of relatively high density. The majority of the residents live in high rise condominiums. Nevertheless, at the very east side of the neighbourhood the architecture is typically low-rise buildings, detached and semi-detached houses. There are multiple road corridors passing through the neighbourhood with high volumes of traffic. There is a dense transportation network of subways, streetcars, busses, and bike paths. The neighbourhood contains a large cluster of shops, retail centers, bars, restaurants, theaters, movie complexes, and other entertainment facilities. Moreover, two universities and multiple government and institutional buildings are located in this neighbourhood. In the north west part of the neighbourhood is Queen's Park Toronto. It is an urban park and the site of the Government of Ontario.

The Don Mills Valley neighbourhood (Banbury - Don Mills) is an uptown neighbourhood. It was developed as a self- supporting town, outside of the city boundaries. However, today this neighbourhood represents a community with low density and high income status. The majority of this area is a residential area with mostly detached houses, and a relatively dense tree canopy throughout the neighbourhood. The main transportation method is the use of personal vehicles. The neighbourhood is surrounded by ravines to the south, east, and west giving home for a wide variety of flora and fauna (Figure 2) and providing access to hike trails and other outdoor activities. Main road corridors give access to highways. Shopping malls can be found close to main intersections.

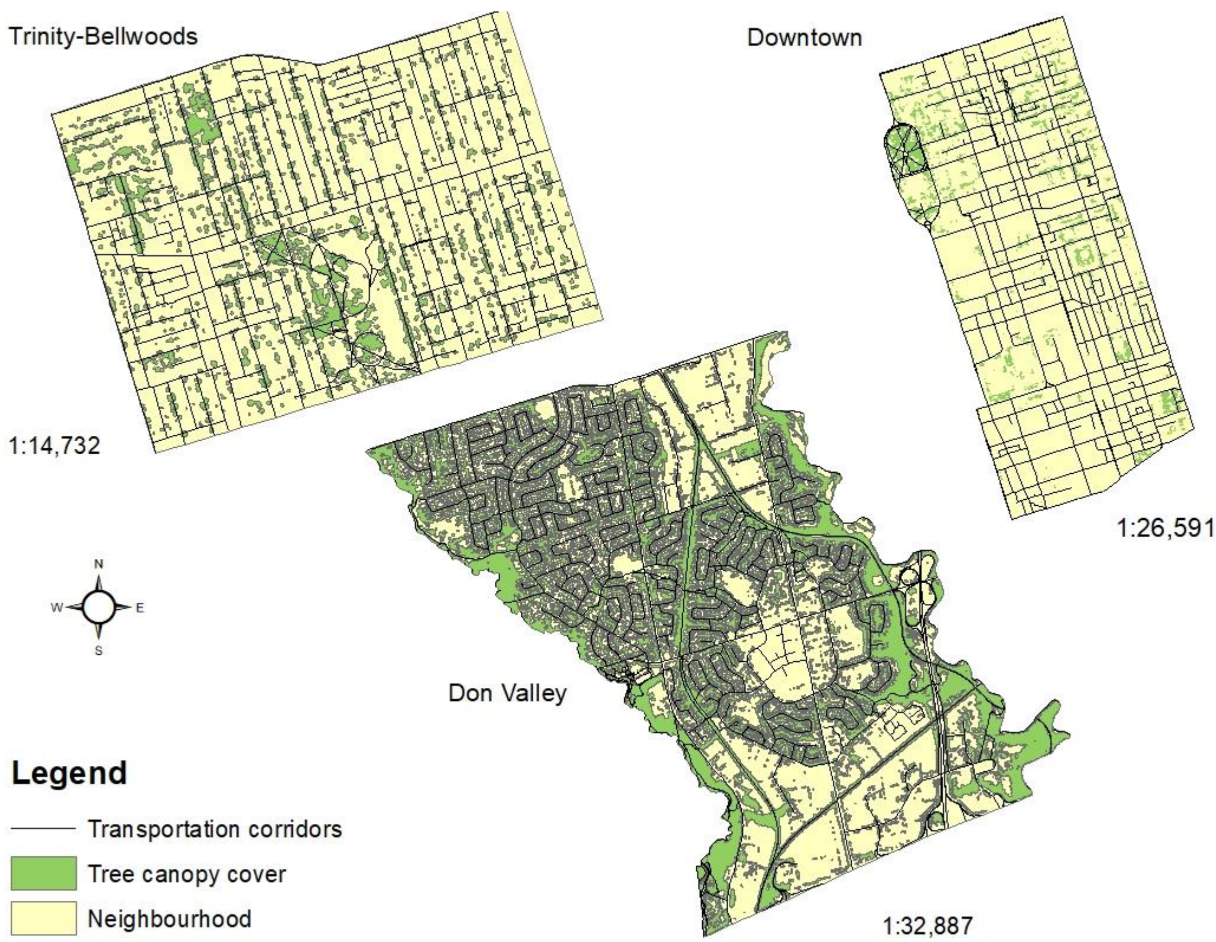


Figure 2. Sampling areas, road network, and tree canopy cover in the three neighbourhoods of interest

2.2.2. Neighbourhood Noise Survey

Residents in the neighborhoods of interest were recruited by postcard invitations to complete an online survey instrument called the "Neighbourhood Noise Survey". The distribution of the post cards took place in July 2017, after the study received ethical approval from Ryerson's Research Ethics Board (REB). Approximately 3000 households were targeted in the 3 neighbourhoods of interest and it achieved a sample size of 552 participants. Survey participant addresses were linked to georeferenced, residential soundscape metrics to characterize their exposures to noise. The format of the questions is similar to the ones previously used in studies of noise annoyance in North America. The online survey started with an introductory page to select persons of age 18 and above and included 38 questions. The survey was designed using ISO/TS 15666:2003 standard questions for assessment of environmental noise annoyance. Specification of wording is based on two questions: 1) verbal rating scale for clear transparent communication: "Not at all?; Slightly?; Moderately?; Very?; Extremely?" and 2) numerical rating scale to verify the consistency of the respondents answers: "what number from 0 (no disturbance) to 10 (intolerable disturbance) best represents how much you are annoyed by noise at home/in the neighbourhood?" (ISO, 2003). The question about noise was phrased as follows: "Thinking about the last 12 months or so, when you are here at home, how much does outdoor noise bother, disturb or annoy you?". A unique approach was used to identify what makes certain soundscape pleasant by asking: "How pleasurable are the sounds you experience when you are in your neighbourhood/outside your dwelling? With a 9- point numerical scale (1-9 with verbal endpoints “very unpleasant” and “very pleasant”). Studies suggest that pleasant sounds can improve the comfort of citizens despite the loudness of the surrounded noises (W. Yang & Kang, 2005). In the questions with a 5-point verbal scale, an annoyance cut-off was used to evaluate high annoyance as responding “very” or “extremely” annoyed. In the questions with 11-point numerical scale, an annoyance cut-off of 7 and above was used to evaluate high annoyance. Similarly, with the 9 –point numerical scale questions, a pleasant sound cut-off of 4 was used to evaluate a pleasant soundscape. Additional questions to collect demographic and socioeconomic information were added in order to test if these factors influence the individual’s noise perception.

2.2.3. Environmental exposure assessment

Environmental noise measurements were obtained from the Environmental Noise Monitoring Study conducted by Ryerson University and Toronto Public Health (Oiamo, 2017). Noise data was collected during the summer, 2016 from 220 point locations in Toronto. These locations cover the entire City of Toronto and were selected randomly and from candidate locations produced in a location-allocation model. Factors such as railways, road network and population densities were used to identify candidate locations. A one week monitoring period per site was chosen to obtain an adequate representation of noise levels during different times of the weekday as well as weekends. Noise was measured using a Noise Sentry RT sound level meter data logger

(Convergence Instruments, Sherbrook, QC, Canada). The sensor is capable of applying A and C weighted functions to all sound measurement, which adjusts the sound pressure levels to account for varying sensitivity at different frequency ranges of human hearing (Oiamo *et al.,* 2017).

Traffic data representing the annual average traffic volume of cars on streets in Toronto was used to model traffic noise and to estimate the proportion of noise from road traffic (Traffic24h). It is well known that buildings can have a strong effect on sound acoustics (Silva, Oliveira, and Silva, 2014). Different metrics to assess noise levels for buildings were developed and building façade reflection were included in the traffic noise model developed in previous research from Oiamo et al. (2017). The current study also utilizes a noise model that represents all existing environmental noise, not just from traffic. The noise assessment for participants in the current study are based on estimated levels surrounding the building façade and estimated levels at street centreline corresponding to the participant's address. Thus, the two variables that controlled for noise exposure are: Façade_levels, and Street_levels.

When using categorical variables, cases were weighted with noise levels cut-off below 55dBA, 55-65dBA, 65 - 75dBA, and above 75dBA. The cut-off is based on the WHO recommended noise levels which are 55dBA (Joseph, 2009). Different time slices of the 24-hour period were modeled for equivalent A-weighted sound pressure levels: 12-hour daytime average (0700-1900[Day]), 8-hour nighttime average (2300-0700[Night]), 24-hour average [24h]. The noise models represent the noise levels experienced by each individual participant in the Neighbourhood Noise Survey.

Different variables of green space that include distance to green space, tree canopy cover in 200m and 500m buffers as well as park cover in 200m and 500m buffers were created. The buffers were chosen based on existing literature. In the report "Urban green spaces and health", the World Health Organization referenced studies using 100m, 200m, 300m, and 500m buffers and recommended a maximum 15 minutes walking distance to a green space (WHO, 2016). Tree canopy cover was chosen as a variable to represent green space in the analysis part of this study. The tree canopy cover around each participant's residence was divided in four groups (quartiles) that represent the same number of residents exposed to each of the quartiles within each neighbourhood. Quartiles is a standard method used in epidemiological and environmental health studies (Gatrell & Elliott, 2009). This method provides a measure of relative green space access within the neighbourhood.

2.3. Analysis

2.3.1. Community Tolerance Levels

The differences in the noise annoyance dose-responses between the study neighbourhoods were examined by the Community Tolerance Level (CTL) method and based on previous research from Fidell *et.al.* (2011) and Schomer *et. al*. (2012). Fidell *et al.* (2011) introduced a theoretical equation (Eq.1) that can predict the percentage of inhabitants that are highly annoyed (%HA) in a community by knowing the day-night average noise levels (DNL) in that community. This equation is based on three assumptions:

1) The exponential function $e^{-1/x}$ creates a transition period (from exponential increase from 0%, to a 100% asymptote), which then allows to select x such that it is a function of DNL (Ldn) and creates a best fit to the data (Fidell et al., 2011).

2) The community annoyance growth rate is dependent on the cumulative sound energy, represented here with the term $10^{Ldn/10}$ (using 10dB base) (Stevens, 1972; Schomer et al., 2012)

3) Finally, assumption 2 requires that the term $10^{Ldn/10}$ be raised to the power of 0.3 power as loudness is roughly proportional to sound pressure raised to the power of 0.3 (Fidell et al., 2011; Schomer et al., 2012).

$$\%HA = 100^{*}EXP(\,-(\,1/[10^{(\frac{Ldn+K}{10})}]^{0.3}))$$

Eq. (1)

Further, the constant K shifts the curve on the x-axis and it has been set to 5.306 dB so that it represents 50% highly annoyed residents (%(HA)=50%). The value of K could be chosen arbitrarily. Nevertheless, Fidell *et al.* (2011) chose 50%HA as an anchor point of the function, which shows the noise level at which half of the community is highly annoyed from noise (Fidell *et al.*, 2011; Schomer *et al.,* 2012). In this study, the same anchor point (K=5.306dB) was chosen to determine the Ldn at which 50% of respondents are highly annoyed.

To include the field observation of surveys, Fidell *et al.* (2011) added another component to the equation, the Community Tolerance Level (CTL) variable [L_{ct}] as shown in (Eq. 2). The L_{ct} is determined empirically through surveys that quantify qualitative aspects of the community and the environment (Fidell *et al.* ,2011), hence it provides “a value with decibel units that characterizes a community” (Fidell et al., 2011, p.793)

$$\%HA = 100^{*}EXP(-(1/(10^{(\frac{Ldn-Lct+5.306}{10})})^{0.3}$$

Eq. (2)

In this study, the L_{ct} values are determined for each studied neighbourhood by using the empirical data of high annoyance responses and the corresponding estimated noise level for the response. This is done by first plotting the collected data (percentage highly annoyed (%HA) and the corresponding noise levels (DNL)) for a particular community on a graph. After, the smooth Eq. 2 is plotted and moved along the x axis (by adjusting L_{ct}) so that it best fits the plotted collected data. The curve that best fits the data is called the CTL curve for that particular community and its L_{ct} value represents the noise level at which 50% of the respondents are highly annoyed (Fidell *et al.*, 2011).

To achieve the best fit, the goal is to minimize the root mean square (RMS) error between the curve and the observations (Green and Fidell, 1991; Schomer *et al.*, 2012). The RMS error is determined by taking a measured %HA value of a particular point and subtracting the %HA from the predicted value (using a particular L_{ct}) to calculate a variance for a particular point. Then, all of the variances are added up for all of the data points and then divided by the number of points, which allows us to compare the variance of the data point. The square root is taken of the final value which gives the RMS error for the particular CTL curve. Finding the best fit requires several attempts with different values of L_{ct}, each producing a different RMS error, and finishing the exercise when the lowest one is found.

2.3.2. Multi-variate analysis

Two different multivariate analyses were used to assess the relationship between noise exposure and human perception of noise. The Classification & Regression Tree (CART) method was used to understand the pleasantness of sound in the neighbourhood. This method is widely used in decision-making processes because of the easy interpretation and illustration of the outcome (Lemon, et al., 2003). CART identifies interactive relationship by reducing the deviance of the response variable. This recursive partitioning method allows splitting the full sample into the most homogeneous subset of explanatory variables in according to the dependent variable (Lemon, et al., 2003). In this study, the CART method was used to determine the explanatory variables for a pleasant soundscape. Therefore, the dependent variable was the binary question: “How pleasurable are the sounds you experience when you are in your neighbourhood/outside your dwelling?”, with answers 0= Unpleasant; 1= Pleasant. The study tested 28 covariates which measured demographic, socio-economic characteristics, health, built environment characteristics, access to green space, and noise variables. The Gini coefficient is reported to indicate to what extent an independent variable splits the sample into homogenous sub-sample according to the dependent variable.

The second multi-variate analysis method was logistic regression. The logistic regression approach is a common approach in socio-acoustic studies, where there is a mixed use of continues and categorical variables. Logistic regression can use both categorical and continuous variables as predictors to understand their effect on a binary outcome variable, which in this case was to show highly annoyance (HA) by noise (giving yes=1 or no=0 answer). A series of models with progressively included predictors based on the theoretical framework were conducted. The models were fitted in the entire sample (n=552). Model 1 tested the differences in the three neighbourhoods. Model 2 added to the neighbourhoods the demographic variables Age and Sex. Model 3 tested the effect of socio-economic factors on high annoyance, as well as on pleasurable soundscape. The socio-economic factors include Housing tenure, Education, and Employment. Model 4 additionally controlled for Noise Sensitivity, self-reported General Health, and Hearing Problems. Model 5 added green space. Model 6 tested the different noise measurements: day noise levels, night noise levels, 24h noise levels, and 24h noise levels from traffic noise, specifically. The odds ratio (OR) generated by the logistic regression are reported to represent the relationship between predictors and highly annoyance. In addition, pseudo R-squared values, the

Hosmer & Lemeshow chi-square goodness of fit measures are reported. All data preparation and analyses were done with SPSS 24 (IBM, Armonk, NY, USA) and ArcGIS 10.4 (ESRI, Redlands, CA, USA).

2.4. Results

2.4.1. Sample characteristics & bivariate analysis

Within the selected neighbourhoods, individuals above 18 years old were chosen for the study. The study recruited 552 participants and overall the response rate was 9%. The responses in Downtown were much higher and constituted 66% of the total sample (Table1). In Trinity-Bellwoods the majority of respondents were in the age category 35-54 (41%). The majority of participants in Downtown were in the categories of age 18-34 and 35-54 at 35% and 32%, respectively. In Don Valley, the majority of respondents were in the category of 55-75 (66%). A higher proportion of males participated in Downtown (60%, male), but the reverse was the case for Trinity-Bellwoods (63%, female) and Don Valley (56%, female). The majority of the respondents in the three neighbourhoods were full-time or self-employed (42 - 62%) and the rest had a mix of different statuses, such as homemaker, retired, and students. In Don Valley, the majority of the respondents were in the category retired and homemakers (45.9%). In all three neighbourhoods about the same proportion of respondents (87 – 89%) had a completed post-secondary school. In all three neighbourhoods the majority of participants self-reported a very good general health (36-43%).

The majority of the residents in Downtown rented their property (62%) but the reverse was the case for Trinity-Bellwoods (63%, owners) and Don Valley (85%, owners). The majority of participants in Trinity-Bellwoods lived in semi-detached houses, in Downtown 53% lived in high-rise building, and in Don Valley the majority of residents lived in detached houses (72%).

Respondents were less sensitive to sound/noise in Downtown (18.4%) than in the two other neighbourhoods (24%). Self-reported of high annoyance at home was higher in Downtown (35.8%) and in Don Valley (32.9%) but lower in Trinity-Bellwoods (20.4%). High annoyance in the neighbourhood had the highest percentage score in Don Valley (36.5%) compared to Downtown (35.8%). Trinity-Bellwoods had the lowest high annoyance rate at 20.4%. Descriptive tables of the predictor variables within the sub-samples of high versus low annoyance at home and in the neighbourhood can be find in Appendix B.

Table 1. Descriptive table of personal variables measured in percentage for the three neighbourhoods and the full sample

Variables		Neighbourhood				
		Full Sample (n=552)	Trinity Bellwoods (n=98)	Downtown (n=369)	Don Mills Valley (n=85)	Chi-Sq. (sign.)
Age (%)	18-34	31.0	33.7	35.5	8.2	54.05 (0.000)
	35-54	33.0	41.8	32.8	23.5	
	55-75	33.5	22.4	29.0	65.9	
	75 and above	2.5	2.0	2.7	2.4	
Gender (%)	Female	47.1	64.3	40.4	56.5	21.30 (0.000)
	Male	52.9	35.7	59.6	43.5	
General Health (%)	Very Good/Excellent	93.8	94.9	93.0	96.5	1.71 (0.426)
	Poor/Fair/Good	6.2	5.1	7.0	3.5	
Hearing problems (%)	No	81.5	79.6	81.8	82.4	0.31 (0.858)
	Yes	18.5	20.4	18.2	17.6	
Noise induced hearing loss (%)	No	94.0	93.9	94.3	92.9	0.23 (0.889)
	Yes	6.0	6.1	5.7	7.1	
Noise Sensitivity (%)	Not at all	42.9	42.9	43.9	38.8	3.22 (0.522)
	Moderately	36.6	32.7	37.7	36.5	
	Very	20.5	24.5	18.4	24.7	
Education (%)	High school	12.0	10.2	12.2	12.9	0.38 (0.825)
	Higher Education	88.0	89.8	87.8	87.1	
Employment (%)	Full-time Job	58.5	57.1	62.6	42.4	20.12 (0.000)
	Part-time job/ Unemployed	10.7	18.4	8.4	11.8	
	Student/Retired/Homemaker	30.8	24.5	29.0	45.9	
High Annoyance at home (%)	Not Annoyed	67.4	79.6	64.2	67.1	8.32 (0.16)
	Highly Annoyed	32.6	20.4	35.8	32.9	
High Annoyance in the neighbourhood (%)	Not Annoyed	67.8	81.6	65.0	63.5	10.58 (0.005)
	Highly Annoyed	32.2	18.4	35.0	36.5	

Table 2. Descriptive table of categorical variables of noise (in dB(A)) and green space measured in percentage for the three neighbourhoods and the full sample

		Neighbourhood				
		Full sample (n=552)	Trinity-Bellwoods (n=98)	Downtown (n=369)	North West Don Valley (n=85)	Chi-Sq. (sign)
Facade level [Lday] (%)	< 55	3.4	7.1	2.7	2.4	68.02 (0.000)
	55 – 65	52.9	77.6	43.4	65.9	
	65– 75	24.1	11.2	26.6	28.2	
	75 dB+	19.6	4.1	27.4	3.5	
Facade level [Lnight] (%)	< 55	37.3	81.6	16.5	76.5	212.63 (0.000)
	55- 65	28.8	12.2	35.5	18.8	
	65 – 75	28.1	5.1	39.6	4.7	
	75 dB+	5.8	1.0	8.4	0.0	
Facade level [L24h] (%)	< 55	13.8	37.8	5.7	21.2	111.74 (0.000)
	55 – 65	48.2	52.0	45.0	57.6	
	65 – 75	23.0	7.1	27.6	21.2	
	75 dB+	15.0	3.1	21.7	0.0	
Street level [night] (%)	< 55	34.6	80.6	11.4	82.4	269.44 (0.000)
	55 – 65	34.4	16.3	45.5	7.1	
	65 – 75	22.5	2.0	30.6	10.6	
	75 dB+	8.5	1.0	12.5	0.0	
Street level [day] (%)	< 55	2.0	1.0	2.7	0.0	64.99 (0.000)
	55 - 65	55.6	81.6	44.2	75.3	
	65 – 75	21.9	14.3	25.5	15.3	
	75 dB+	20.5	3.1	27.7	9.4	
Street level [24h] (%)	< 55	3.3	4.1	3.5	1.2	71.24 (0.000)
	55 – 65	58.5	83.7	46.6	81.2	
	65 – 75	18.5	9.2	22.5	11.8	
	75 dB+	19.7	3.1	27.4	5.9	
Traffic [24h] (%)	<55	44.7	80.6	32.5	56.5	91.59 (0.000)
	55 – 65	28.8	16.3	31.2	32.9	
	65 – 75	26.3	3.1	36.0	10.6	
	75 dB+	0.2	0.0	0.3	0.0	

The noise assessment analysis showed that in the three neighbourhoods, the majority of citizens are exposed to Façade day time noise levels between 55-65dB(A) (Table 2). However, at night the Façade level of Downtown Toronto is above the threshold of 55dBA, while the majority of residents in the other two neighbourhoods were below this threshold. The chi-square tests showed the differences observed between the expected frequencies and the actual data. There was a significant association between each noise variable and the neighbourhood variable ($p<0.001$).

The differences in noise levels between the three neighbourhoods are illustrated as continues variables in Table 3, which reflected the differences observed among categorical noise exposure. It can be observed that the mean residential Street level night time noise levels were similar in Trinity-Bellwoods (53.47 dB(A)) and Don Valley (53.15 dB(A)), but in Downtown the mean night time noise level was much higher (64.38 dB(A)). Similar results can be observed with the other noise metrics. The continuous variable of green space showed that the mean of the tree canopy cover in Trinity-Bellwoods is 15%, comparable to 13% in Downtown and much lower than Don Valley where it was 45%. The range of categorical Tree Canopy cover value based on quartiles within each of the three neighbourhoods also showed notable higher levels in Don Valley, where residents in the highest quartile had more than 50% cover around their residence (Table 4).

Table 3. Descriptive table of continuous variables of noise (in dB(A)) and green space for the three neighbourhoods and the full sample with F-test value and significance

	Full Sample					F (sig.)
	Mean	Median	St. Dev.	Min	Max	
Facade level [L24h]	64.0	62.2	8.4	45.6	82.2	78.50 (0.000)
Street level [24h]	65.5	62.7	7.7	50.0	83.4	46.24 (0.000)
Traffic [24h]	58.6	56.0	7.5	42.0	76.0	44.64 (0.00)
Facade level [Lday]	65.9	63.6	8.0	46.9	85.0	8.30 (0.000)
Street level [day]	66.5	63.7	7.6	43.5	85.0	35.59 (0.000)
Facade level [Lnight]	60.4	59.9	9.5	43.7	77.6	162.77 (0.000)
Street level [night]	60.7	58.8	9.1	40.5	82.3	132.27 (0.000)
Tree Canopy in 500m	0.18	0.14	0.12	0.02	0.55	1007.13 (0.000)
Trinity-Bellwoods						
Facade level [L24h]	57.6	56.3	5.9	49.7	82.1	
Street level [24h]	60.4	59.4	5.1	53.5	83.3	
Traffic [24h]	53.2	52.0	5.0	47.0	75.0	
Facade level [Lday]	60.5	59.0	5.9	51.9	85.0	
Street level [day]	61.9	60.8	5.1	54.9	84.8	
Facade level [Lnight]	52.4	50.8	6.2	44.7	76.0	
Street level [night]	53.5	52.3	5.0	46.9	76.3	
Tree Canopy in 500m	0.15	0.15	0.04	0.06	0.22	
Downtown						
Facade level [L24h]	66.7	64.8	8.1	45.6	79.6	
Street level [24h]	67.5	64.6	7.8	50.0	83.4	
Traffic [24h]	60.4	58.0	7.7	42.0	76.0	
Facade level [Lday]	68.1	66.1	8.1	46.9	81.6	
Street level [day]	68.2	66.1	7.9	43.5	85.0	
Facade level [Lnight]	64.5	64.2	8.1	48.1	77.6	
Street level [night]	64.4	62.2	8.3	40.4	82.3	
Tree Canopy in 500m	0.13	0.12	0.06	0.02	0.27	
Don Valley						
Facade level [L24h]	59.3	57.2	5.8	51.0	72.8	
Street level [24h]	62.6	60.7	5.5	53.6	80.2	
Traffic [24h]	56.9	55.0	5.9	47.0	75.0	
Facade level [Lday]	63.1	61.1	5.6	54.8	75.8	
Street level [day]	64.3	62.4	5.5	55.2	81.9	
Facade level [Lnight]	52.0	49.4	6.3	43.7	66.1	
Street level [night]	53.1	51.3	6.2	44.6	72.6	
Tree Canopy in 500m	0.45	0.46	0.08	0.21	0.55	

Table 4. Descriptive table of Tree Canopy Cover ratio in 500m variable split into 4 quartiles for each of the three neighbourhoods

Tree Canopy Cover in 500m	Trinity-Bellwoods	Downtown	Don Valley
1st quartile	<= 0.11	<= 0.09	<= 0.42
2nd quartile	0.11 - 0.15	0.09 - 0.12	0.42 -0 .46
3rd quartile	0.15 - 0.16	0.12- 0.18	0.46 - 0.50
4th quartile	0.16+	0.18+	0.50+

2.4.2. Pleasurable soundscape environment variables

The results from the recursive partitioning of the full sample by Façade night time noise levels (L night) produced the most homogenous groups (Figure 3). Those exposed to 55dBA or less at night were more likely to report pleasant soundscape around their residence (Gini coefficient = 0.021). Further homogenizing of those exposed to equal or less than 55dBA was from Noise Sensitivity. In this subgroup it can be seen that the residents who were not sensitive are more likely to sense a pleasant soundscape. The covariate Age further split the sub-sample for those exposed to decibels level higher than 55dBA into homogenous groups. It can be seen that the age group between 35-75 was more likely to experience unpleasant soundscape.

The recursive partitioning method was also applied to the three neighbourhood sub-sample. For Trinity-Bellwoods and Downtown, the Noise Sensitivity variable produced the most homogeneous groups (Figure 4 and Figure 5). In Trinity-Bellwoods, Very Sensitive respondents were equally likely to report a pleasant or unpleasant environment, but the Not Sensitive respondent group was more likely to perceive the environment as pleasant. Further homogenizing of the Not Sensitive respondent group was from their employment status, with people with primarily home based occupations were more likely to report an unpleasant environment (35%) compared to those with full-time and part-time jobs (11%) (Figure 4). In Downtown, further homogenizing of the Not Sensitive respondent group was from Façade night time noise level (Gini coefficient = 0.014). Those exposed to less than 55dBA were more likely to perceive the environment as pleasant (65%), compared to those exposed to higher than 55dBA (45%) (Figure 5). In contrast, the CART analysis for Don Valley showed that the most homogeneous group was produced by the Building type variable with a Gini coefficient of 0.058 (Figure 6). While the majority of respondents in this neighbourhood live in detached houses, the participants from the few low-rise and high-rise buildings were more likely to perceive the environment as unpleasant (80%). Among those living in detached and semi-detached houses, participants living in detached houses were more likely to perceive unpleasant environment (33%), compared with those living in semi-detached houses (0%).

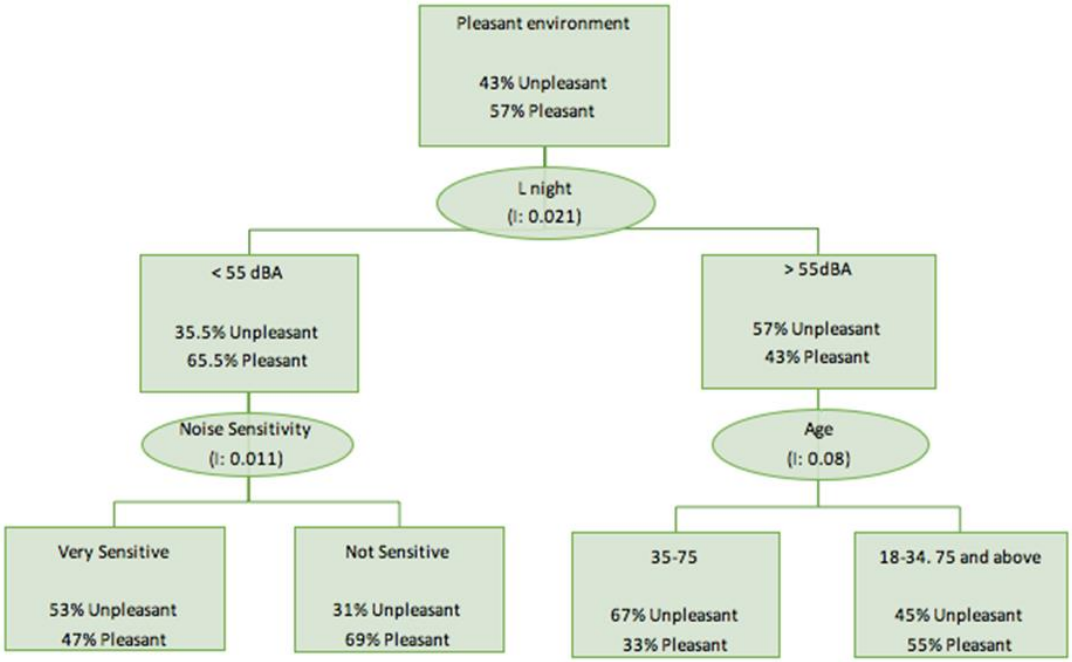


Figure 3. Classification and Regression Tree analysis for pleasant soundscape in the full sample

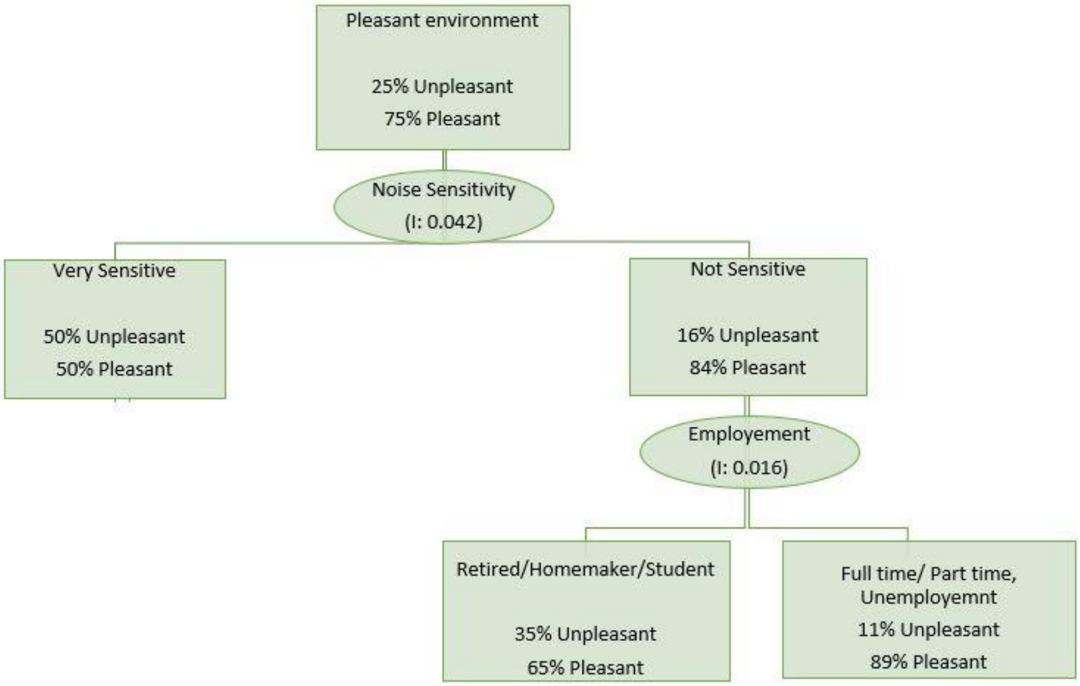


Figure 4. Classification and Regression Tree analysis by pleasant soundscape in Trinity-Bellwoods sub-sample

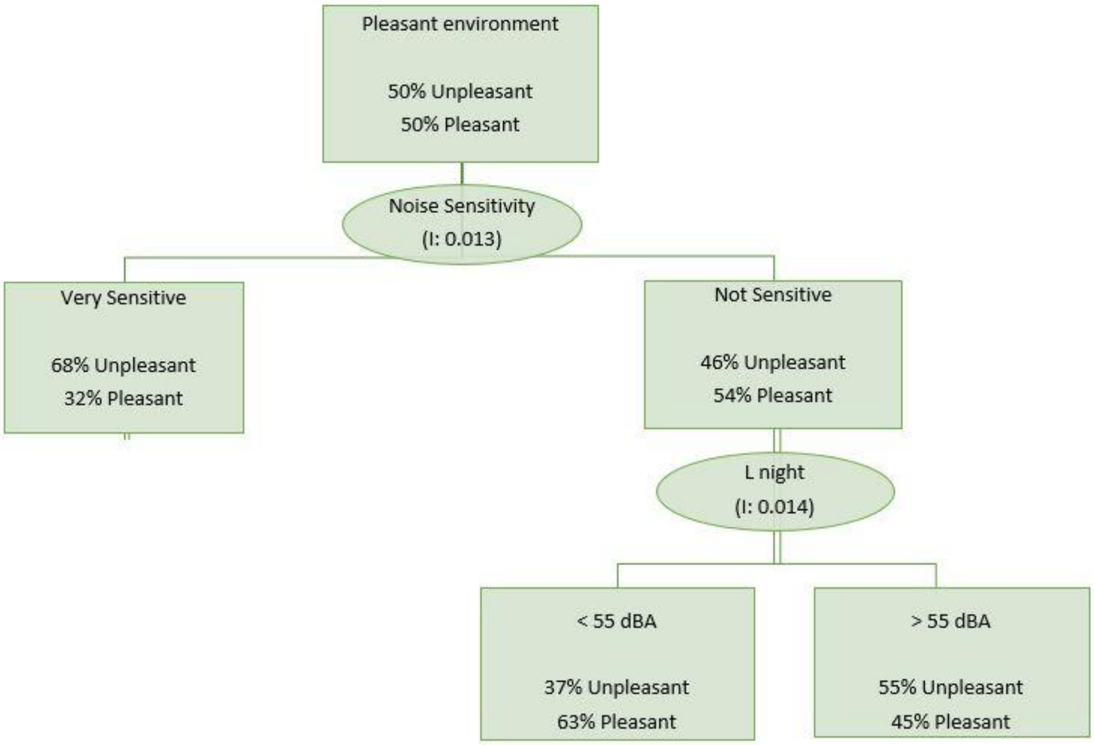


Figure 5. Classification and Regression Tree analysis for pleasant soundscape in Downtown sub-sample

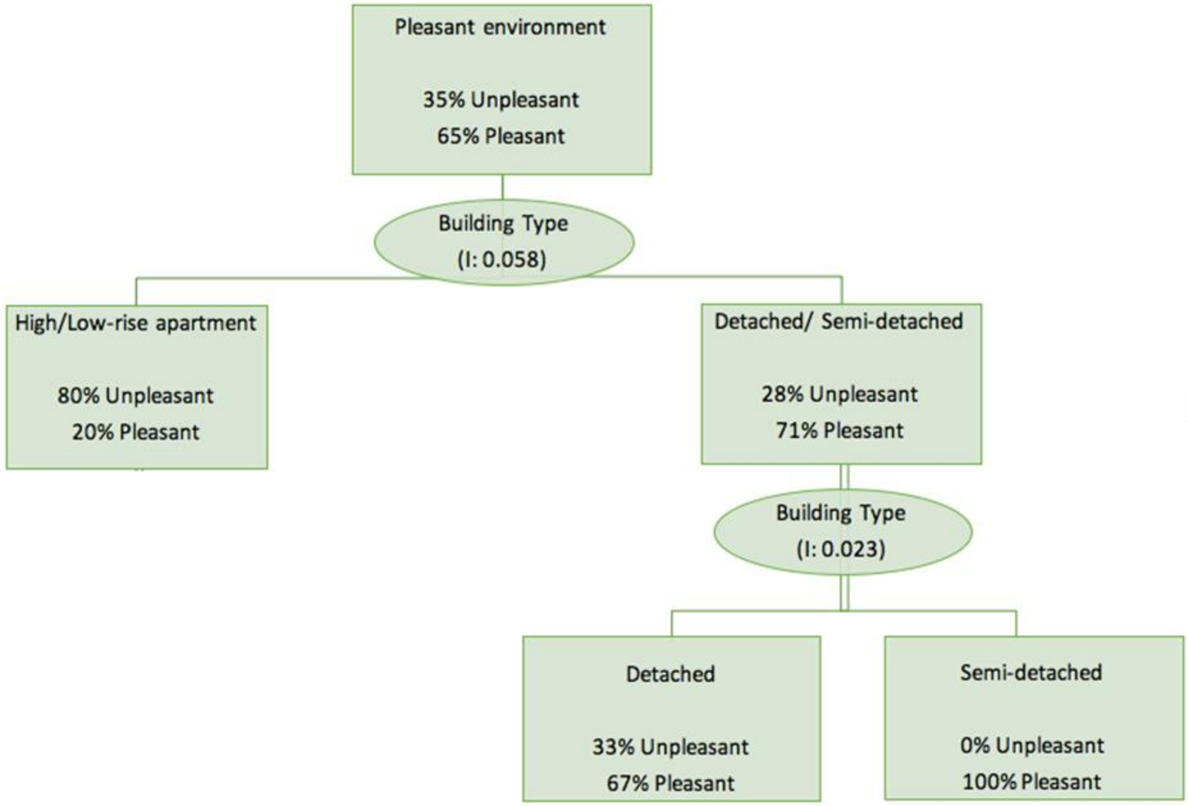


Figure 6. Classification and Regression Tree analysis for pleasant environment in Don Valley sub-sample

2.4.3. Community Tolerance Levels

Analysis of noise annoyance by estimating CTLs suggested that different environmental contexts in the three neighbourhoods influenced the dose-response relationship between noise levels and annoyance. Fitting the survey data to the effective loudness function demonstrated some consistency with the dose-response curve proposed by Fidel et al. (2011) (Figure 7). However, the relatively small sample size may have prevented a better fit to the predetermined curve. The estimated CTL of 74 dB(A) based on the best RMSE (5.45) for Trinity-Bellwoods neighbourhood had a R^2 value of 0.69. This implied that 50% of the participants of the survey in Trinity-Bellwoods were highly annoyed by environmental noise levels at 74 dB(A). Similarly, the estimated CTL for Don Valley neighborhood was 77 dB(A), with the best RMSE (6.17) and a R^2 value of 0.75. In Downtown Toronto we observed that the CTL is much higher as 50% of the participants were highly annoyed by environmental noise at 84 dB(A). The sample size was higher in Downtown which allowed for better fit of the curve, and therefore lower RMSE compared to the other two CTL curves, (RMSE = 4.42; R^2 = 0.92). The Downtown CTL curve suggests that the highest noise exposures correspond to a higher tolerance level. Furthermore, the overall tolerance level in Toronto based on the three neighbourhoods is 83 dB(A).

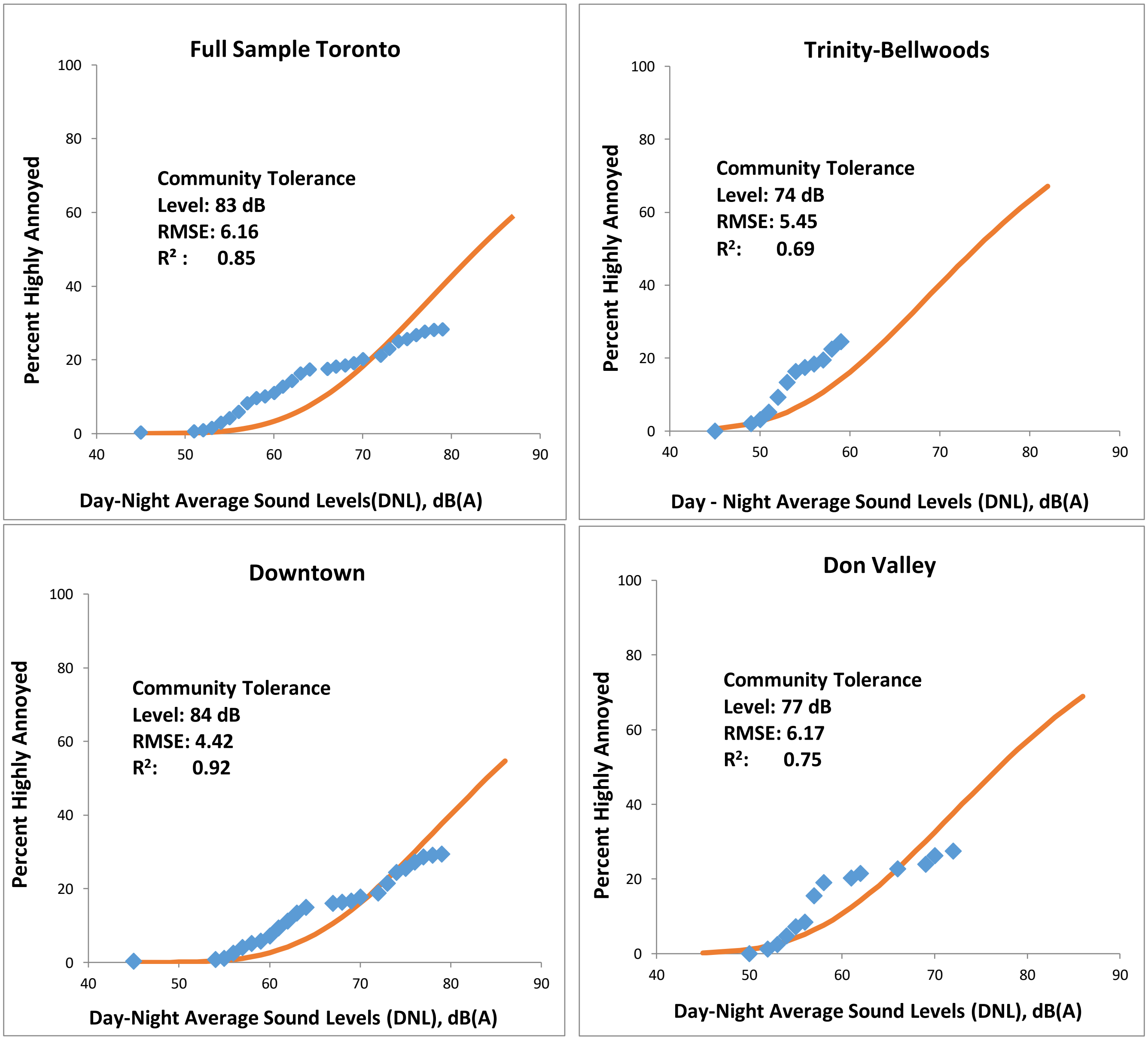


Figure 7. Best fit curve for survey data on high annoyance to effective loudness function in the Full sample, Trinity-Bellwoods, Downtown, and Don Valley

2.4.4. Logistic Regression on high annoyance at home

The regression models were based on self-reported high annoyance from the answers of the question: “Thinking about the last 12 months or so, when you are here at home/in the neighbourhood, how much does outdoor noise bother, disturb or annoy you?” with the outcome of participants that self-reported being highly annoyed. This logistic model on noise annoyance at home demonstrated that residents in Downtown Toronto were 2.17 ($p<0.01$) times more likely to report higher level of annoyance when being at home than residents in Trinity-Bellwoods neighbourhood (Table 5). The significance of the Downtown neighbourhood remained throughout the models, except when controlling for night time noise. The age categories 35 -54 and 55-74 were significant, and therefore a strong predictor for high annoyance. When controlling for socio-economic factors it was observed that home owners were 1.90 ($p<0.01$) times more likely to report high annoyance at home, compared with people that rent their homes. Model 4 controlled for noise sensitivity, where the results were expected. People who responded high sensitivity were 5.96 ($p<0.001$) times more likely to be highly annoyed compared with not sensitive people. The self-reported Somewhat sensitive had a 2.73 ($p<0.001$) higher likelihood to report high annoyance, compared to not sensitive people. When controlling for green space it was observed that participants with the slightly less access to green space (3rd quartile), compared to those with the most access to green space (4th quartile), were 2.14 ($p<0.01$) times more likely to be highly annoyed when they are at home.

For model Model 6 different noise variables were tested. The results showed that there was no significant effect on noise annoyance at home from day time noise exposure and 24hours noise exposure. However, night time noise levels were a significant predictor for high annoyance. Where those exposed to levels between 55 to 65dB(A) compared with those exposed to below 55dB(A) were 2. 76 ($p<0.01$) times more likely to be highly annoyed. Moreover, noise annoyance increased with noise levels. For example, those exposed to levels above 75 dB(A) were 3.78 ($p<0.01$) times more likely to report high annoyance, compared to those exposed to 55dB(A). When controlling for night time noise levels, the significance of the Downtown neighbourhood disappeared, and the significance of tree canopy cover diminished. Removing the neighbourhood variable from the model slightly increased the effect of noise on annoyance, but did not change the effect of other covariates (Appendix C).

2.4.5. Logistic Regression on high annoyance in the neighbourhood

Interesting differences were observed comparing high annoyance reported at home versus in the neighbourhood. Residents in Downtown and Don Valley were 2.39 ($p<0.01$) and 2.55 ($p<0.05$) likely to report high annoyance in their neighbourhoods compared to Trinity-Bellwoods, respectively (Table 6). However, after controlling for sex and age in Model 2, the effects of residing in Don Valley disappeared, but for Downtown Toronto remained. Similar to the logistic regression analysis of high annoyance at home, the age category 35-74 and noise sensitivity were also significant predictors for high annoyance in the neighbourhood. Controlling for tree canopy cover showed significance as a predictor for high annoyance. It was observed that residents in the lowest quartile were not more annoyed compared with those with the highest access to tree canopy cover, while residents in the 2nd and 3rd quartile were more likely to report high annoyance. When controlling for tree canopy cover there was a shift in the neighbourhood significance as a predictor for high annoyance. The effect of residing in Downtown increased to 2.47 ($p<0.01$), and also Don Valley had a likelihood of high annoyance 2.31 ($p<0.05$) times higher than Trinity-Bellwoods. The significance of Don Valley remained when controlling for each noise variable.

The results from the logistic regression model on high annoyance in the neighbourhood showed that night time noise levels were still a strong predictor for high annoyance. Residents exposed to 55 to 65dB(A) were 2.35 ($p<0.05$) more likely to report high annoyance compared with those exposed to below 55dB(A). Furthermore, when controlling for night time noise levels the significance of Downtown disappeared, but for Trinity-Bellwoods slightly increased. Residents in Don Valley were 2.35 times more likely to be highly annoyed compared with the residents in Trinity-Bellwoods. A notable increase of the likelihood of high neighbourhood noise annoyance with an increase of 24h noise levels was also observed. Those exposed to 55 - 65dB(A) were 5. 97($p<0.05$) times more likely to report high annoyance compared to those exposed to below 55dB(A). Further, those exposed to 65-75dBA were 6.29 ($p<0.05$) times more likely to be highly annoyed. Similar to annoyance at home, removing the neighbourhood covariate increased the effect of noise, but did not change the effect of other covariates (Appendix C).

Table 5. Logistic regression model for noise annoyance at home

Parameter estimates	FULL SAMPLE Q9_ Highly Annoyance at Home							
	Neighb, hood (Exp. B)	Demographic (Exp. B)	Socio-economic (Exp. B)	Health (Exp. B)	Tree Canopy in 500m (Exp.B)	Street level Day (Exp. B)	Street level Night (Exp. B)	Street level 24h (Exp. B)
(Reference: Trinity)								
Downtown	2.17**	2.25**	1.85**	1.98**	2.14*	2.34**	1.12	2.28**
Don Valley	1.92	1.43	1.47	1.51	1.62	1.66	1.68	1.62
Age (*Reference: 18-34*)								
35-54		2.40***	3.16***	3.34***	3.50***	3.53***	3.58***	3.46***
55-74		3.11***	3.69***	3.62***	3.55***	3.61***	3.58***	3.53***
75 and above		1.64	1.49	1.27	1.26	1.23	1.34	1.24
Sex *(Reference: Female)*		0.98	0.95	1.12	1.07	1.03	1.08	1.06
Housing tenure (*Reference: Owners)*			1.90**	1.90**	1.85**	1.94**	1.63*	1.86**
Noise Sensitivity (*Reference: Not Sensitive*)				***	***	***	***	***
Somewhat sensitive				2.73***	2.80***	2.73***	3.15***	2.85***
Highly sensitive				5.96***	6.15***	6.06***	6.96***	6.31***
Tree Canopy in 500m (*Reference: quartile 4)*						*	*	*
Quartile 1					1.45	1.53	1.23	1.54
Quartile 2					1.77	1.91*	1.62	1.87*
Quartile 3					2.14**	2.34**	1.94*	2.33**
Noise (*Reference: below 55dBA)*							*	
55-65dBA						2.75	2.76**	2.30
65-75sBA						2.03	2.20*	1.75
Above 75dBA						2.62	3.78**	2.29
Hosmer & Lemeshow χ2 (df), significance	0.00(1), 1.00	7.41(8), 0.49	6.14(8), 0.63	11.73(8) 0.16	6.01(8), 0.65	2.49(8), 0.96	4.20(8), 0.84	2.13(8), 0.98
Nagelkerke R2	0.02	0.08	0.11	0.22	0.24	0.25	0.26	0.25

p<0.1, *p<0.05, **p<0.01, ***p<0.00

Table 6. Logistic regression model for noise annoyance in the neighbourhood

Parameter estimates	FULL SAMPLE Q11_ Highly Annoyance in the neighbourhood							
	Neighb, hood (Exp. B)	Demog raphic (Exp. B)	Socio-economi c (Exp. B)	Health (Exp. B)	Tree Canopy in 500m (Exp.B)	Street level Day (Exp. B)	Street level Night (Exp. B)	Street level 24h (Exp. B)
(Reference: Trinity)								
Downtown	2.39**	2.46**	2.06*	2.22*	2.47**	2.61**	1.47	2.70**
Don Valley	2.55**	1.87	1.92	2.08	2.31*	2.33*	2.35*	2.32*
Age (*Reference: 18-34*)		***	***	***				
35-54		2.29**	2.82***	2.81***	2.97***	3.02***	3.01***	3.01***
55-74		3.22***	3.94***	3.60***	3.50***	3.55***	3.51***	3.46***
75 and above		1.67	1.75	1.40	1.39	1.33	1.50	1.32
Sex *(Reference: Female)*		0.98	0.96	1.08	1.03	1.01	1.05	1.03
Housing tenure (*Reference: Owners)*			1.73*	1.69**	1.62*	1.64*	1.43	1.56
Noise Sensitivity (*Reference: Not Sensitive*)				***	***	***	***	***
Somewhat sensitive				3.26***	3.43***	3.34***	3.74***	3.54***
Highly sensitive				5.72***	6.07***	6.17***	6.66***	6.43***
Tree Canopy in 500m (*Reference: Quartile 4)*					**	**	*	*
Quartile 1					1.43	1.54	1.22	1.57
Quartile 2					1.88*	1.88*	1.74	1.82
Quartile 3					2.52**	2.64**	2.40**	2.78***
Noise (*Reference: below 55dBA)*								
55-65dBA						5.35	2.35*	5.97*
65-75sBA						5.84	2.10*	6.29*
Above 75dBA						5.02	2.16	5.12
Hosmer & Lemeshow χ2 (df), significance	0.00 (1), 1.00	10.08(8), 0.26	5.83(8), 0.67	14.21(8), 0.08	6.91(8), 0.55	5.13(8), 0.70	3.66(8), 0.89	9.40(8), 0.31
Nagelkerke R2	0.03	0.08	0.11	0.23	0.25	0.26	0.26	0.26

p<0.1, *p<0.05, **p<0.01, ***p<0.001

2.5. Discussion

In essence, the goal of this research was to better understand the relationship between noise annoyance and noise exposure by identifying the community level sensitivity and predictors for noise annoyance. Overall, the study confirmed previous findings that demonstrated the effects of demographic and socio-economic covariates on the effects of noise exposure (Dale et al., 2015; Fields, 1993; Fyhri and Klaeboe, 2006; Genuit and Fiebig, 2006; Michaud et al. 2005). Specifically, the CART analysis showed that the built environment influenced the perception of pleasant environment in the Don Valley neighbourhood, while socio-economic and individual characteristics were more important indicators of perceived pleasant environment in the Trinity-Bellwoods and the Downtown neighbourhoods.

The CTL approach showed that the communities exposed to lower noise levels corresponded to lower tolerances of noise and vice versa. These results also showed that there were differences in the noise annoyance dose-response in the three neighbourhoods. Trinity-Bellwoods and Don Valley had similar noise exposure at night (53dBA) but participants in Don Valley were two times more likely to report high annoyance, even though night time noise levels were lower. Conversely, participants in Downtown and Don Valley had similar noise responses despite the differences in noise exposure. These results suggest that noise exposure cannot solely predict noise annoyance, but rather that non-acoustic factors are influential to noise perception and noise annoyance responses.

The dose-response relationship between noise exposure and noise annoyance were linked with noise sensitivity. This study found that the three neighbourhoods had different community level sensitivities. While participants in the two neighbourhoods Trinity-Bellwoods and Don Valley had similar percentage rates of self-reported sensitivity, their CTLs differed slightly. However, this should be interpreted with caution as the CTL curve did not fit well with the data and the sample size was relatively small. Yet, this study supported previous studies researching the dose-response relationship between noise exposure and noise annoyance (Fidell et al., 2011; Schomer et al., 2012; Oiamo et al. 2015). While Fidell et al. (2011) and Schomer et al. (2012) used the CTL approach to investigate the community level of sensitivity in individual cities around the world, the current study applied the CTL approach in different neighbourhoods within a city. The results reflect previous findings by Oiamo *et al.* (2015), which showed differences in noise sensitivity at the neighborhood-level in Windsor, Ontario. The current study confirmed that noise tolerance varies between neighbourhoods in the city of Toronto. Together these studies suggest that neighbourhood level environmental context and noise tolerance should be considered when assessing noise impacts on health and wellbeing at the scale of cities.

For example, in Downtown Toronto the noise sensitivity (18%) was lower than the other two neighbourhoods, which corresponded with a higher observed CTL at 84dBA. These results were expected, since persons that are less sensitive to noise may not prioritize noise when choosing a location to live in (Oiamo et al., 2015). In Downtown Toronto, gentrification and attraction to a “center location” brings citizens that want to live in central areas, despite the elevated noise levels. Naturally, center locations are associated with higher noise levels due to clusters of pedestrian and vehicle traffic, businesses, and cultural and recreational activities (Fyhri and Klæboe, 2006). Further interpretation of these results may pose the question: Does lower sensitivity denote lower vulnerability to adverse health effects from noise? This research cannot solely solve the problem of understanding sensitivity. Noise sensitivity has been largely ignored in various epidemiological and biomedical research on noise and health due to its complexity. There are still uncertainties about the knowledge of noise sensitivity coming from the fact that sensitivity is, as of yet, a non-unitary concept (Job, 1999; Miedema and Vos, 2003; Oiamo et al., 2015). Nevertheless, several studies have investigated the relationship of noise sensitivity and health (Dratva et al., 2010; Fyhri & Klaeboe, 2008; Nitschke, Tucker, Simon, Pisaniello, & Hansen, 2014; Shepherd et al., 2010).

Shepherd et al. (2010) investigated the relationship between environemntal noise and health-related quality of life (HRQOL) in Auckland, New Zealand. The research demonstrated a correlation between noise sensitivity and noise annoyance. Moreover, they reported that annoyance and sleep disruption are mediators of noise sensitivity and as such noise sensitivity might degrade HRQOL. Further to this, the current study presented evidence that noise sensitivity appeared as an influential factor in all of the three analysis used in this thesis. There is no apparent physiological explanation for the differences in noise perception between the three neighbourhoods that explains why citizens in Downtown are less sensitive to or less annoyed by noise. Therefore, context and environment in relation to noise exposure are influential factors of noise annoyance. This assertion was confirmed in the findings of Oiamo et al. (2015), which suggested that "the effect of noise sensitivity on noise annoyance differs with environmental context" (p.192). It is important to gain better understanding of the link between noise sensitivity, noise annoyance, and quality of life to ensure sustainable future urban development in Toronto and elsewhere.

This phenomenon of neighbourhood sensitivity can be further explained by the differences in built form and residential density between Downtown and Don Valley (Tang & Wang, 2007; Irvine et al., 2009; Sanchez et al., 2016). For example, the types of noise are different in the two neighbourhoods. The background noise in Downtown, in its majority, is defined by traffic, HVAC systems from commercial and institutional buildings, amplified sound from bars, and the general "hum" of the city. Additionally, the street canyon effect occurs between high-rise buildings, an architectural type particular for Downtown Toronto. Also, traffic noise can increase due to continued long building line in streets, which is also a characteristic of Downtown built form (Heutschi, 1995). In contrast, Don Valley's built form in most of its part is residential area, lacking the "hum" of the busy Downtown streets. The detached houses with a wide area between each property and higher tree canopy cover compose a different sonic and visual environment. Not only is the ambient noise lower compared with Downtown Toronto, but also the characteristics of noise in Don Valley are more so home equipment, such as leaf blowers, HVAC, and other machinery. In such environments, peak noise events, such as the sound of a passing ambulance, or an air plane corridor, might be more noticeable. Therefore, the reaction to these peak noise events can contribute to elevated noise annoyance and higher sensitivity, despite the relatively low noise levels. Further, factors such as aging of buildings and floor of occupation might be influential to individual's noise sensitivity and annoyance, however the tests of these variables in the current study did not show significance.

Miedema and Vos, (2003), reported that sensitivity might be related with general environmental dissatisfaction. They stated that more sensitive people might perceive with greater concern potential or more existing environmental problems (Miedema and Vos, 2003). While Don Valley neighbourhood is seen as neighbourhood with high environmental quality (e.g. access to green space; low crime), which should not correspond to dissatisfaction of the environment, participants in Don Valley might perceive the noise pollution as a greater problem than it actually might be. In contrast, participants in Downtown have the right to claim their dissatisfaction from the environment and particularly the sonic environment, because the noise levels are much more elevated (L night=64dB(A). In this sense, the distribution of noise tolerance in Toronto might be helpful in developing noise mitigation policy, because noise complaints are not necessarily from individuals with the greatest cause for complaints.

One important feature of environmental context that may be related to noise sensitivity is access to green space. Tree canopy cover appeared to influence noise annoyance in this study. It was observed that residents living in the central neighbourhoods with the least access to green space, were actually less annoyed compared to residents with higher access to tree canopy cover in Don Valley. Conversely, there was an effect of lower tree canopy cover within neighbourhoods, which increased the likelihood of noise annoyance. Gidlöf-Gunnarsson and Öhrström, (2007) found that greater availability to green space of residents of Stockholm was related with reduced long-term noise annoyance. The results of this study confirm that this may be the case within neighbourhoods in Toronto. However, it is difficult to interpret how the higher tolerance to noise among downtown residents influences the effect of tree canopy on annoyance. Differences in the cultural and environmental context of Toronto and Stockholm may also be important.

The findings in the current study suggest that there is a certain threshold of green space above which people develop an expectation of the environment and are more likely to report high annoyance from noise. Similar to the current study, Brambilla and Maffei, (2006) reported that "the more the sound is congruent with the expectation" of an environment the less respondents will have high annoyance (Brambilla & Maffei, 2006, p. 881). They investigated noise surveys and subjective appraisals of three urban parks in Naples, Italy. Brambilla and Maffei (2006) observed that participants' expectations to hear a particular sound in a specific environment influences their annoyance. In regards to the current study, the findings showed that participants in Downtown and Trinity-Bellwoods had the least access to green space and potentially lower expectations of the soundscape. In contrast, participants in Don Valley had the highest access to green space and it could be implied that they have certain expectations of the environment.

These expectations of the environment could be supported by the concept of high property value. A variety of research on urban green space shows that distribution of urban green space addresses environmental justice problems, where access to green space and high tree canopy cover is associated with higher property value (Byrne, Wolch, & Zhang, 2009; Checker, 2011; Wolch, Byrne, & Newell, 2014). While this study is not looking at environmental justice issues, this occurrence suggests that citizens with higher property values, which is often related with greater access to green space and tree canopy cover, might have higher expectations of the environment and therefore higher expectations of the soundscape.

The influence of demographic and socio-economic factors was also observed through age, education, and income. It was shown that the age group 55-75 was more likely to report high annoyance. In a Canadian national survey on noise annoyance, Michaud et al. (2005) confirmed that residents of 65 years and above are among the most likely to report high annoyance. Education did not have an influence on annoyance rating, which is comparable to the results obtained by Fields (1993). Additionally, participants from Don Valley, the neighbourhood with presumably the highest income earners, were more likely to report high annoyance. These findings confirmed the findings of Michaud et al. (2005) on noise annoyance based on a national survey in Canada, where they suggested that high income is related with high annoyance. The same study was conducted a few years later, where Michaud et al., (2008) reported that 6.7% of all 2565 participants of the national survey in Canada are highly annoyed from road traffic. With respect to these findings, this study showed that 32% of 552 participants were likely to report high annoyance. It is important to note that this study investigated the noise annoyance from all environmental noise, which includes traffic noise, in one of Canada's most urbanized environments.

2.6. Limitation and future research

One of the most significant challenges for noise research is that current methods for assessing noise exposure are not aligned well with the current knowledge about perceptions of noise. Current regulations and guidelines, have been developed based on the outcomes of various epidemiological studies, and they have predominantly used exposure assessments based on A-weighted decibel levels (dBA) averaged over 24 hours of different times periods of the day; also referred to as equivalent sound pressure levels (Leq) (WHO, 2009). The logarithmic sound pressure level (dB) is consequently weighted across the frequency spectrum to represent human sensitivities to different noise frequencies (e.g. A-weighting) (Fletcher and Munson, 1933). A-weighting was designed in 1933 by Fletcher and Munson as a curve that represents noise levels heard by healthy human ear (Fletcher and Munson, 1933). Although equivalent sound pressure levels are the most common noise metrics, their use has been criticized because of the limitation on exposure assessment (Wood, 2011; Schomer et al. 2013; De Roos *et al.*, 2014) . The metric provides information on loudness; however, it does not provide identification of different types of sound, which may lead to an incomplete understanding what type of noise exposure a community is experiencing (Schomer *et al*., 2012). Despite the loudness, other factors such as irregular intervals of sound exposures, and distinct sounds are found to affect individuals' noise perception (Tang and Wang, 2007).

Another limitation due to the sample size is the limitation of the study to investigate the sub-samples of logistic regression model. Defining the predictors of noise annoyance for each individual neighbourhood would strengthen the current results of the full-model study. Moreover, the limited sample size posed difficulties to determine the best fit curve of the CTL approach. However, the results were consistent with other studies in similar environments. The results did show that lower sound levels correspond to lower tolerance to noise. Further research is needed to determine CTL as a useful tool to differentiate the influence of contextual factors on noise responses.

2.7. Conclusion

This study found that levels of noise exposure in the three neighbourhoods in the city of Toronto are higher than recommended noise levels. The World Health Organization (WHO) recommends night time noise levels of 45dBA with an important threshold of 55 dB(A); levels above this threshold are associated with serious annoyance and potential negative health outcomes (Berglund et al. 1999). In respect to the three neighbourhoods, Trinity-Bellwoods and Don Valley have an average night time noise levels 52-53dB(A), that are close to the interim targets of WHO. However, in Downtown

Toronto the average night time noise levels are 64 dB(A) which exceeds the WHO recommended night time noise levels.

This thesis showed that participants in Downtown and Don Valley had similar noise responses (35.8% and 32.9% high annoyance) despite the differences in noise exposure (66.7dBA and 59.3dBA (L24h)). Which confirmed that noise exposure cannot solely predict noise annoyance. The study found that predictors of noise annoyance responses are the built environment, green space, noise sensitivity, and night time noise levels variables.

Lastly, this thesis showed that the Don Valley neighborhood has presumably the highest income, the highest access to green space, and relatively low night time noise levels but participants’ expectations for tranquility and relatively low tolerance makes them more annoyed, specifically two times more likely to report high annoyance, when evaluating the neighbourhood soundscape. Not discussed in other studies, the findings of this thesis suggest that high environmental quality might be related with high expectations. For future research on noise perception, the results warrant explicit consideration of shared neighbourhood perception of noise and environmental expectations.

3. CHAPTER THREE

3.1. Outcome of thesis objectives

In the outcomes of the first research objective, the study did confirm that there are notable differences in noise responses between the three neighbourhoods. The descriptive analysis showed that Downtown and Don Valley had similar noise responses, specifically the majority of the two neighbourhoods self-reported high annoyance, despite the differences in noise exposure and built form between the two neighbourhoods. Where the majority of participants of the survey in Trinity-Bellwoods reported not being annoyed, despite the similarity of noise exposure and noise sensitivity with the Don Valley neighbourhood.

In regards to the outcomes of the second research objective, the study confirmed previous findings of Schomer et al. (2012) where the participants exposed to lower sound levels had a lower tolerance of noise. Furthermore, Schomer at al. (2012) study showed that the average CTL is 78.3dB(A) based on survey data from road traffic annoyance from around the world. The current study showed that the effective loudness function for Toronto defines 50% of the researched population to be highly annoyed at 83dB(A). It can be concluded that CTL is a useful tool to differentiate the influence of contextual factors on noise responses. Nevertheless, the limitation of this study due to small sample size may pose a challenge. It can be observed that with a larger data set, such as the one from Downtown Toronto, the curve achieved a better fit to the predetermined function.

The outcomes of the third research objectives, showed that the variables: built environment, green space, noise sensitivity, night time noise levels are predictors for high annoyance responses. Also the findings of this study suggest that environmental context influences expectations and sensitivity to noise. Since, even after controlling for all kinds of contextual factors: noise levels, socio-economic factors, built environment, and individuals' characteristics; participants in Don Valley were still two times more likely to report high annoyance, when evaluating the neighbourhood soundscape. Having the highest income, highest percentage of green space, and robust social capital their expectation for tranquility and relatively low tolerance might make the participants in Don Valley more annoyed. Further research is required to investigate the role of physical and individual characteristics in perception of noise both in individual and neighbourhood level.

3.2. Conclusion and policy implication

Building on the psychological and physiological stress perspective, this thesis considers annoyance as a health outcome. As such, annoyance is seen as a stress response to noise. This study demonstrated that the shared neighbourhood perception of noise is an important consideration in understanding noise perception. Therefore, this thesis contributes to the broader research on soundscape, stress responses, and specifically noise perception. Efforts to understand individuals' noise perceptions (e.g. (Fields, 1993; Job, 1999; Miedema & Vos, 2003; Oiamo, Luginaah, & Baxter, 2015) may benefit from applying individual and community perceptions of noise. Furthermore, research in this area should account for high expectations related to high environmental quality, which may cause annoyance. The concept of social capital may support this assertion. As shown in this study, the Downtown neighbourhood lacks the sense of shared community; hence it can be associated with lower social capital. This may imply that there is less concern for the neighbourhood and the natural resources. Therefore, the citizens in Downtown have less expectations for the environment; thus, they are less annoyed. Conversely, Don Valley can be associated with robust social capital, where community cohesion is much in control of the environment, insuring high quality of life in the neighbourhood, which may be associated with higher sensitivity, and noise annoyance.

A soundscape approach can enhance legislative approaches for environmental health; its use was proposed in various emerging studies (Pijanowski et al., 2011; Schomer et al., 2013; Thorne & Shepherd, 2013; Oiamo, 2014) where "quiet" is defined as an "environmental value". The soundscape approach suggests that a psychoacoustic continuum is more amenable for enhancing wellbeing and the quality of life of citizens, rather than solely reducing noise levels (Thorne & Shepherd, 2013; Oiamo, 2014). This thesis provides new opportunities for soundscape measurements by investigating factors that influence the perception of a pleasurable environment. The results demonstrated that certain factors, such as noise sensitivity and built form, are likely to influence the perception of a pleasurable environment. Specifically, built environment had influence on perception of pleasurable environment in the Don Valley neighbourhood. While socio-economic and individuals' characteristics were more important indicator of perceive pleasurable environment in the Trinity-Bellwoods and the Downtown neighbourhoods. As seen in this thesis, participants from the Don Valley neighbourhood that live in detached houses were more likely to perceive an unpleasant environment, compared to those living in semi-detached houses. Thus, the pleasant environment model supplemented the assertion that higher social capital is related with higher expectations of the environment. As such, the current study contributes to the broader research on soundscape, where the account of pleasant environment may be beneficial in this area of research.

Recognizing noise as a human health burden increases the pressure on cities to address noise exposures. The City of Toronto is one of the cities that faces challenges to tackle environmental noise. This is exemplified by Toronto Public Health, which recently conducted its first comprehensive noise exposure assessment study (Oiamo, 2017). The study showed that citizens of Toronto in all areas of the city are exposed to noise levels higher than the World Health Organization (WHO) guidelines. Recommended next steps include a noise management strategy, where a crucial step is to define reasonable noise thresholds for daytime and nighttime limits in the city of Toronto (Oiamo, 2017). The current study provided an unconventional method of defining noise thresholds by the CTL approach of group sensitivity to noise. Expanding this approach to multiple neighbourhoods in Toronto may be beneficial in better understanding and visualising the community perception of noise. This thesis demonstrated that night time noise levels are an important consideration for a noise management strategy. The current study showed that even after controlling for different kinds of contextual factors, night time noise levels appear to be a significant predictor for noise annoyance. This can be explained by the influence of other factors on noise at night (Miedema, 2007; WHO, 2009; Oiamo, 2017). At night there is less variation of noise. Traffic contributes more to the variation of noise at night compared to other times of the day (Oiamo, 2017). More precisely, it was estimated that more than 50% of variations in environmental noise in the city of Toronto are explained by traffic noise emissions (Oiamo, 2017). Therefore, the night time model in this study is the most correlated with traffic noise.

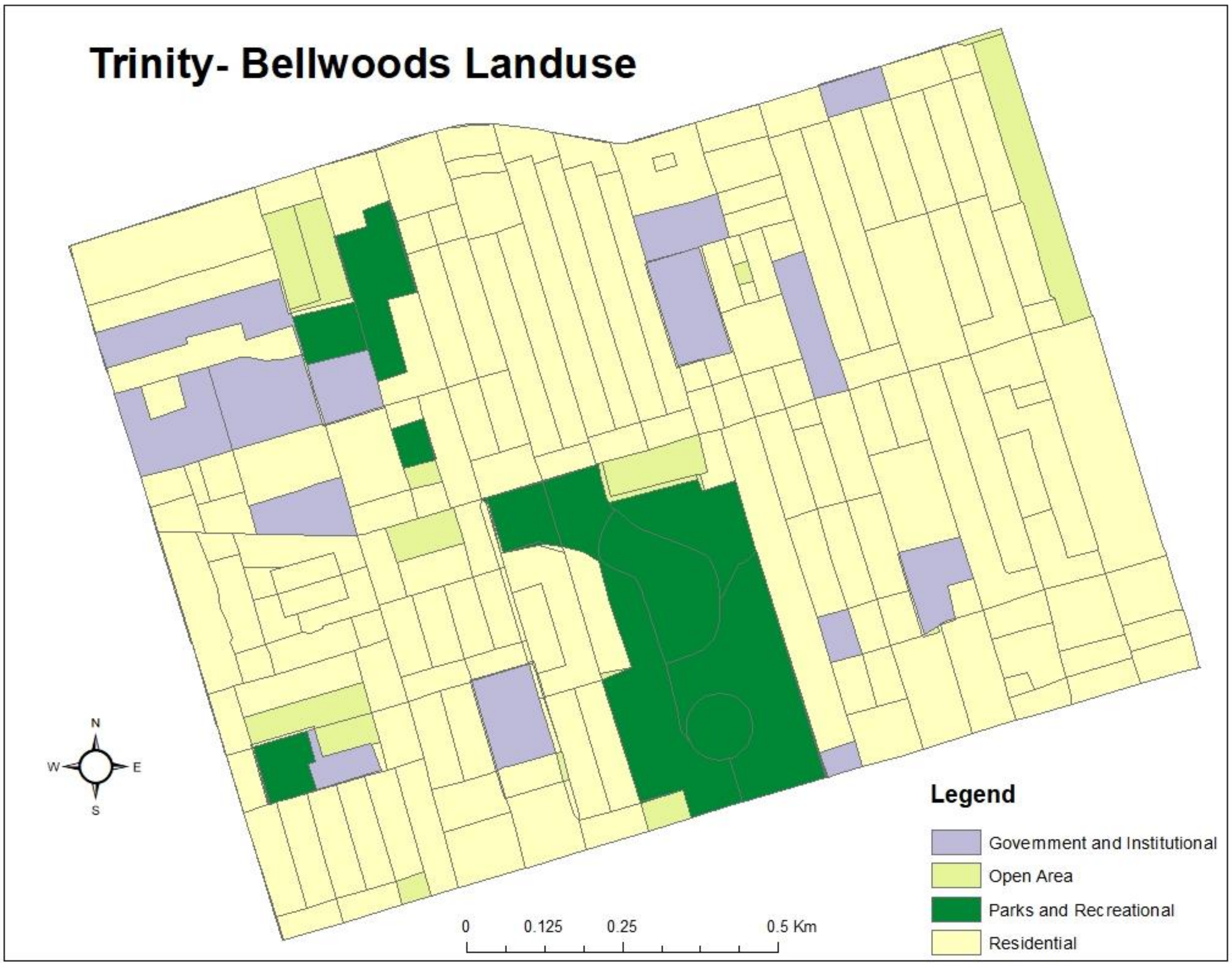
Traffic noise is arguably one of the main environmental health burdens in cities (European Commission, 2000). For example, in Europe, the acknowledgment of the relationship between noise annoyance from traffic and public health, lead to the development of *Sixth Environmental Action Programme* (2001). The main goal of this programme is to provide a noise policy that will reduce "the number of people regularly affected by long-term average levels of noise, in particular from traffic…" and thus, to reduce the number of people annoyed from traffic noise (European Commission, 2000, p.10). While reducing traffic could be achieved in various ways, from speed limits and dynamic traffic management, to the use of electric vehicles, the most multifunctional benefit likely comes from the presence of green space and vegetation. The effect of the gradient of access to green space is shown as a value of noise mitigation factor

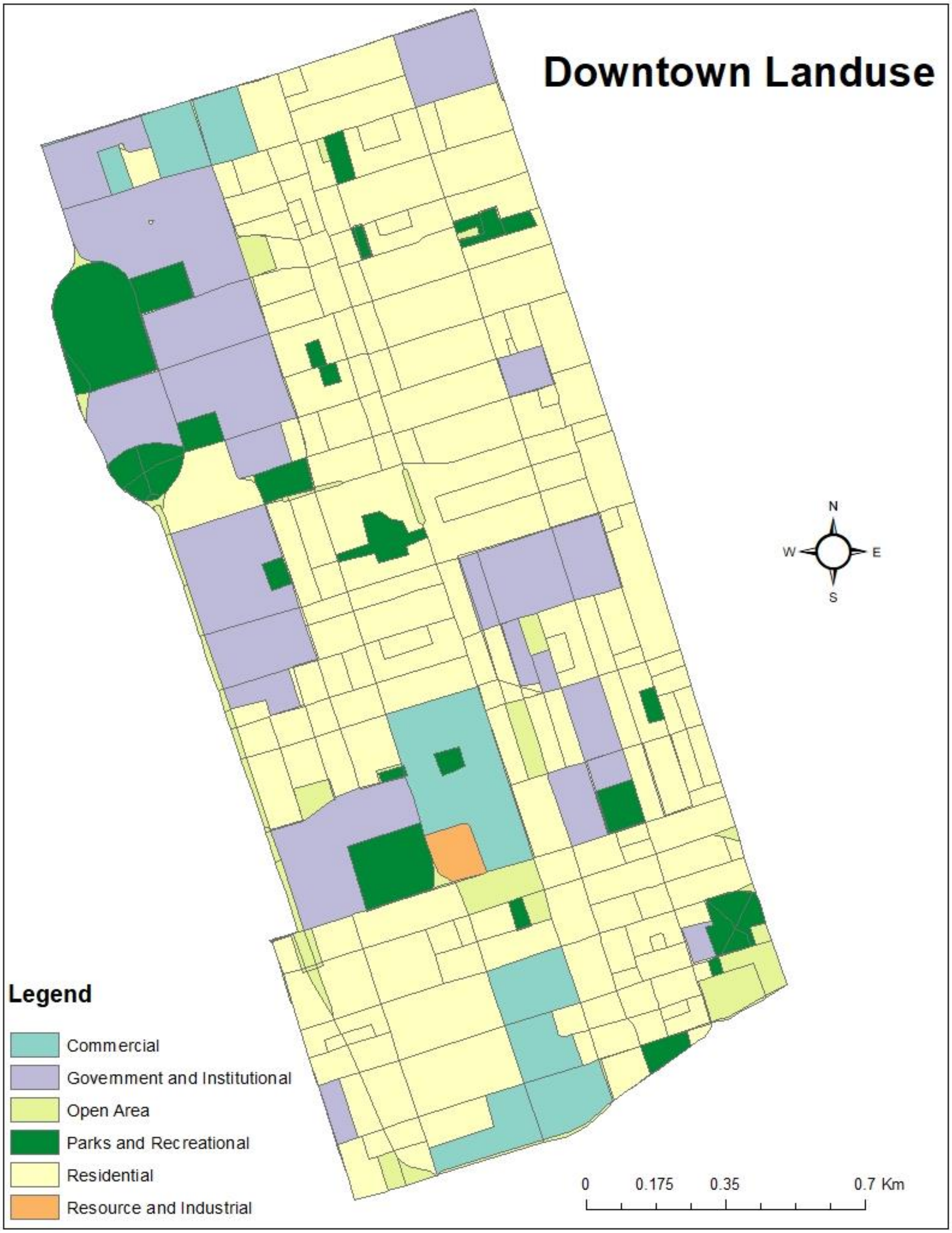
(Huddart, 1992; Fang & Ling, 2005; Ariza-Villaverde et al., 2014). In the current study, this value has shown to be consistent, despite the differences in built form and socio-economic factors between the three neighbourhoods. The value of green space as a noise mitigation factor is also an indirect factor for health. It has been shown that increasing of access to green space decreases the risk of mortality (Crouse et al., 2017). Whatever mechanism might feasibly exist, green space is of importance to promote greater health by inducing positive emotions, reducing mental exhaustion, and providing other psychophysiological responses and restorative values (Kaplan & Kaplan 1989; Ulrich et al., 1991; Mitchell & Popham, 2008; Shepherd, et al., 2013; Thompson et al., 2016). Despite the multiple benefits of green space on human health, there is a gap of understanding how much green space is "enough". For example, the latest report from the WHO "*Urban Green Space and Health*" (2016) shows how various studies are providing different characteristics of accessibility, quality, and size of green space. This demonstrates that there are difficulties to quantifying the access of green space. This thesis contributes to the broader area of research on green space and public health, by demonstrating that just a little green space may not be enough, but higher access to green space my cause soundscape expectations that can lead to annoyance.

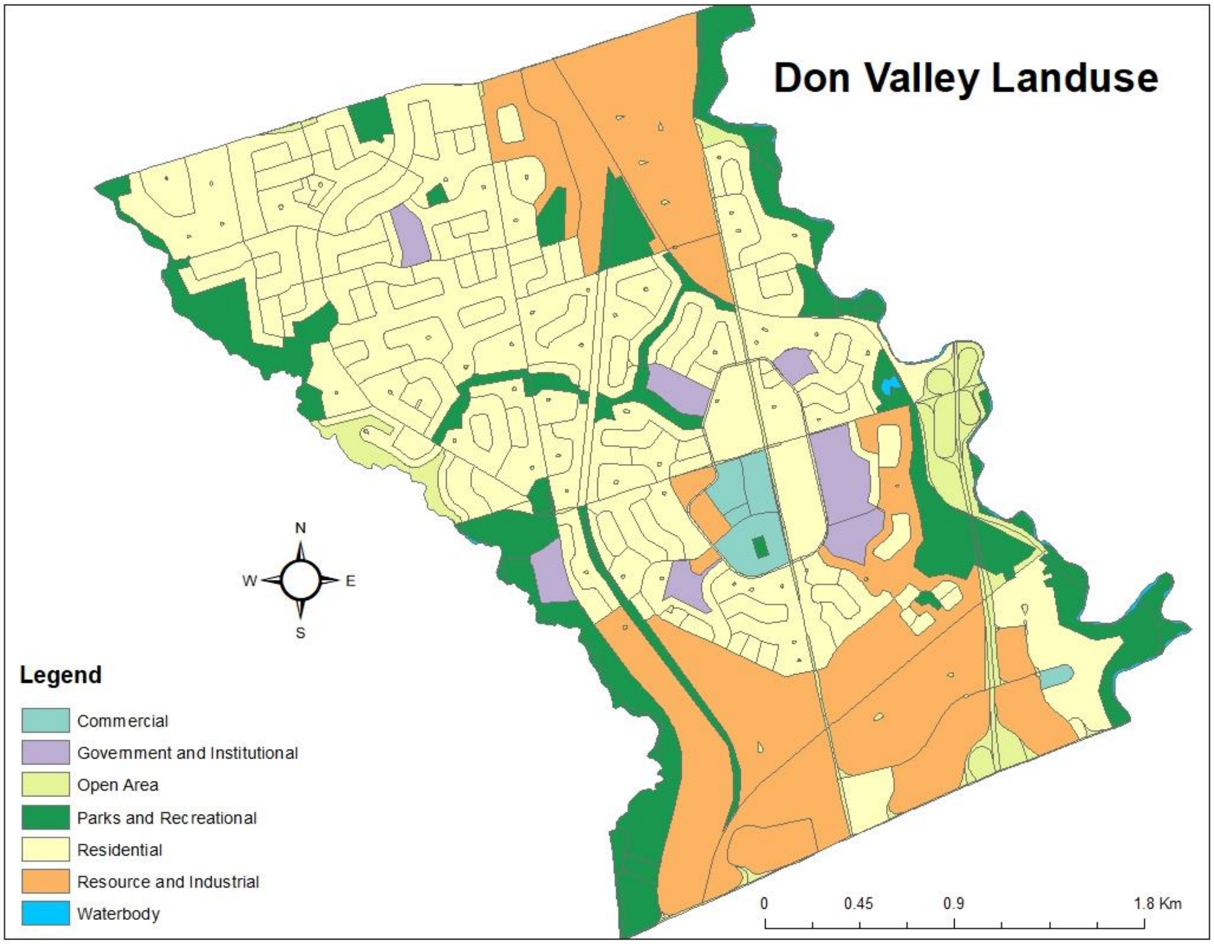
Research on the relationship of risk responses, noise exposure, and public health needs to continue to advance the growing knowledge surrounding noise perception. Previous research in this area certainly provided support for the current knowledge base. However, the research that increasingly recognizes the systematic health risks in everyday life, and the complexity of noise perception in regard to psychological and physiological health outcomes, fails to address noise sensitivity. Furthermore, focusing only on reducing environmental noise exposure, divorced from the social and environmental context, is likewise a reductionist approach. However, recent emerging approaches in soundscape and the promotion of good sound in cities holds great promise for future noise management plans that are interdisciplinary and policy relevant.

Appendices

Appendix A: Study Area




Downtown Landuse
N
W
E
S
Legend
Commercial
Government and Institutional
Open Area
Parks and Recreational
Residential
Resource and Industrial
0
0.175
0.35
0.7 Km


Don Valley Landuse
N
W
E
S
Legend
Commercial
Government and Institutional
Open Area
Parks and Recreational
Residential
Resource and Industrial
Waterbody
0
0.45
0.9
1.8 Km

Appendix B: Descriptive tables of personal variables in sub-samples of High Annoyance at home and in the neighbourhood

		Q9 High Annoyance at home		
		Not Annoyed	High Annoyed	Chi-Sq. (sign.)
Age (%)	18-34	36.8	18.9	20.343 (0.000)
	35-54	31.5	36.1	
	55-75	29.0	42.8	
	75 and above	2.7	2.2	
Gender (%)	Female	47.8	45.6	0.256 (0.613)
	Male	52.2	54.4	
General Health (%)	Very Good/Excellent	95.7	90	6.816 (0.009)
	Poor/Fair/Good	4.3	10	
Hearing problems (%)	No	81.7	81.1	0.30 (0.863)
	Yes	18.3	18.9	
Noise induced hearing loss (%)	No	94.4	93.3	0.225 (0.635)
	Yes	5.6	6.7	
Noise Sensitivity (%)	Not at all	52.4	23.3	50.184 (0.000)
	Moderately	33.6	42.8	
	Very	14	33.9	
Education (%)	High school	10.8	14.4	1.571 (0.210)
	Higher Education	89.2	85.6	
Employment (%)	Full-time Job	60.8	53.9	4.351 (0.114)
	Part-time job/ Unemployed	11.3	9.4	
	Student/Retired/Homemaker	28	36.7	

		Q11 High Annoyance in the neighbourhood		
		Not Annoyed	High Annoyed	Chi-Sq. (sign.)
Age (%)	18-34	36.9	18.5	22.742 (0.000)
	35-54	32.1	34.8	
	55-75	28.3	44.4	
	75 and above	2.7	2.2	
Gender (%)	Female	47.9	45.5	0.269 (0.604)
	Male	52.1	54.5	
General Health (%)	Very Good/Excellent	95.7	89.9	7.102 (0.008)
	Poor/Fair/Good	4.3	10.1	
Hearing problems (%)	No	82.9	78.7	1.437 (0.231)
	Yes	17.1	21.3	
Noise induced hearing loss (%)	No	95.7	90.4	5.965 (0.015)
	Yes	4.3	9.6	
Noise Sensitivity (%)	Not at all	52.9	21.9	51.580 (0.000)
	Moderately	32.4	45.5	
	Very	14.7	32.6	
Education (%)	High school	10.7	14.6	1.753 (0.186)
	Higher Education	89.3	85.4	
Employment (%)	Full-time Job	59.9	55.6	2.083 (0.353)
	Part-time job/ Unemployed	11.2	9.6	
	Student/Retired/Homemaker	28.9	34.8	

Appendix C: Logistic regression models for noise annoyance at home and in the neighbourhood, without the neighbourhood variable

FULL SAMPLE Q9_High Annoyance at home							
	Demographic (Exp. B)	Socio-economic (Exp. B)	Health (Exp. B)	Tree Canopy in 500m (Exp.B)	Total Day (Exp. B)	Total Night (Exp. B)	Total 24h (Exp. B)
Age (*Reference: 18-34*)							
35-54	2.24***	3.18***	3.38***	3.50***	3.51***	3.60***	3.46***
55-74	2.87***	3.82***	3.81***	3.73***	3.80***	3.87***	3.71***
75 and above	1.58	1.56	1.34	1.32	1.26	1.35	1.28
Sex *(Reference: Female)*	1.09	1.02	1.21	1.17	1.14	1.09	1.17
Housing tenure (*Reference: Owners)*		2.14***	2.17***	2.13***	2.18***	1.59	2.08***
Noise Sensitivity (*Reference: Not Sensitive*)							
Somewhat sensitive			2.71***	2.77***	2.72***	3.11***	2.83***
Highly sensitive			5.74***	5.87***	5.85***	6.88***	6.04***
Tree Canopy in 500m (*Reference: quartile 4)*							
Quartile 1				1.40	1.41	1.24	1.41
Quartile 2				1.69	1.78	1.61	1.74
Quartile 3				1.99**	2.09**	1.91*	2.04**
Noise (*Reference: below 55dBA)*							
55-65dBA					2.06	2.46***	1.86
65-75sBA					1.78	2.04*	1.69
Above 75dBA					2.44	3.41**	2.30
Hosmer & Lemeshow χ2 (df), significance	5.38(5), 0.37	6.41(8), 0.60	7.03(8), 0.53	5.87(8), 0.66	6.04(8), 0.64	13.00(8), 0.11	6.02(8), 0.75
Nagelkerke R2	0.53	0.10	0.21	0.23	0.236	0.260	0.232

p<0.1, *p<0.05, **p<0.01, ***p<0.001

FULL SAMPLE Q11_High Annoyance in the neighbourhood								
		Demographic (Exp. B)	Socio-economic (Exp. B)	Health (Exp. B)	Tree Canopy in 500m (Exp.B)	Street Level Day (Exp. B)	Street Level Night (Exp. B)	Street Level 24h (Exp. B)
Age (*Reference: 18-34*)								
	35-54	2.16**	2.85***	2.87***	2.98***	3.02***	3.03***	3.02***
	55-74	3.11***	4.22***	3.98***	3.87***	3.89***	3.97***	3.82***
	75 and above	1.64	1.84	1.51	1.45	1.41	1.56	1.40
Sex *(Reference: Female)*		1.09	1.03	1.17	1.13	1.12	1.07	1.15
Housing tenure (*Reference: Owners)*			1.91**	1.88**	1.83**	1.79**	1.39	1.72**
Noise Sensitivity (*Reference: Not Sensitive*)								
	Somewhat sensitive			3.23***	3.37***	3.31***	3.68***	3.48***
	Highly sensitive			5.49***	5.76***	5.90***	6.55***	6.09***
Tree Canopy in 500m (*Reference: quartile 4)*								
	Quartile 1				1.39	1.42	1.23	1.41
	Quartile 2				1.77	1.75	1.70	1.66
	Quartile 3				2.29**	2.31**	2.27**	2.34**
Noise (*Reference: below 55dBA)*								
	55-65dBA					4.06	2.22**	4.71
	65-75sBA					5.14	2.10**	5.88**
	Above 75dBA					4.72	2.09	5.05**
Hosmer & Lemeshow χ2 (df), significance		5.34(5), 0.37	4.77(8), 0.78	15.22(8), 0.05	10.97(8), 0.20	7.63(8), 0.47	3.67(8), 0.88	12.44(8), 0.13
Nagelkerke R2		0.06	0.09	0.21	0.23	0.241	0.251	0.242

p<0.1, *p<0.05, **p<0.01, ***p<0.001

Appendix D: Letter of information and online survey

Urban soundscapes and wellbeing: assessing the effects of neighbourhood context on environmental noise perceptions

Your household has been selected to participate in an online survey amongst residents of Toronto neighbourhoods. The survey is part of a study being conducted by researchers at Ryerson University and Toronto Public Health to understand perceptions of neighbourhood noise and their relation to noise exposure. Your answers will remain confidential and are for research purpose only.

By completing the survey before <closing date>, You will be entered into a draw for a chance to win 1 of 3 $100 VISA Gift Cards.

How to participate? Go to <site>. It will take approximately 10 minutes to answer a set of questions.

Must be aged 18 or older to participate and preferably the household member whose birthday is next.

Questions? We can be reached by email at tor.oiamo@ryerson.ca

This research study has been reviewed by the Ryerson University Ethics board

RYERSON UNIVERSITY
Consent to Participate in Research

Urban soundscapes and wellbeing: assessing the effects of neighbourhood context on cognitive evaluations of environmental noise

Principal Investigator:

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  Department of Geography and Environmental Studies, Ryerson University

Co-Investigators:

- Frank Russo
  Professor
  Department of Psychology, Ryerson University

INTRODUCTION AND PURPOSE:
My name is Tor Oiamo, and I am a professor in the Department of Geography and Environmental Studies. Together with a colleague in the Department of Psychology and a graduate student at Ryerson, I would like to invite you to take part in my research study, which concerns the relationship between noise perception and exposures to environmental noise in Toronto.

The study is designed to understand and compare perceptions of environmental noise among residents of different neighbourhoods in Toronto. This information will be combined with data on noise levels and types of sounds that characterize the neighbourhood in which you live, also referred to as a neighbourhood soundscape. The main outcomes of the study will be to understand how residents in different neighbourhoods perceive their surrounding soundscapes, whether or not such perceptions differ between neighbourhoods, and finally, if such perceptions correspond to ways in which neighbourhoods are commonly assessed in terms of noise exposure and soundscape quality. You are among approximately 5000 residents in your surrounding area that have been asked to participate. The only requirement for participation in this study is that you are over the age of 18. The results of this study will contribute to publication in scientific journals, the completion of graduate thesis requirements, as well as ongoing efforts to understand the impacts of noise on residents of Toronto.

WHAT YOU ARE BEING ASKED TO DO:
You are being asked to voluntarily complete this on-line survey. It involves questions about neighbourhood noise and sound environments, your dwelling as it affects noise exposure, and some general information about you and your household. It should take about 10 minutes to complete. In order for all of your answers to be collected you must go to the end of the survey and click 'submit survey'. This will demonstrate your full consent to participation.

POTENTIAL BENEFITS:
There is no direct benefit to you for taking part in this study. It is hoped that the research will inform current efforts to develop noise mitigation strategies for cities in Ontario and more generally advance our understanding of urban sound environments (i.e., soundscapes). We hope that you will be interested in seeing the results of the study, and will therefore provide summary information and links to more detailed reports produced from the study on this website as soon as possible.

WHAT ARE THE POTENTIAL RISKS TO YOU?
Some of the survey questions may make you uncomfortable or upset or you may simply wish not to answer some questions. You are free to decline to answer any questions you do not wish to answer, or stop participating at any time by closing your browser. If you close your browser before getting to the end of the survey and do not confirm your consent to participate at the end of the survey by clicking the 'submit' button your information collected up to that point will not be used.

YOUR IDENTITY WILL BE ANONYMOUS:
The survey is anonymous and as such will not be collecting information that will easily identify you, like your name or other unique identifiers. Although your Internet Protocol (IP) address can be tracked through the survey platform, the researcher/s will not be collecting this information. Your IP address may be observed only to ensure that no more than two individuals are completing the survey and that it is not completed multiple times. Please note, however,

that you will be given the option to enter a draw for a $100 Visa Gift Card for your participation at the end of the survey. In order to contact you if you win, we will need some information that may identify you. This information will be treated strictly confidential and kept separate from the survey data by directing you to a separate survey website that cannot be linked to the noise survey responses.

HOW YOUR INFORMATION WILL BE PROTECTED AND STORED:
This survey uses the proprietary survey platform Opinio, which is hosted by Computing and Communications Services at Ryerson University. The servers are located at Ryerson University, therefore no survey information will be available to a third party or disclosed to a Canadian government agency unless required by law. This can occur in rare cases where survey responses provide incriminating evidence. To further protect your information, data stored by the researcher will be password protected and/or encrypted. Only the researchers named in this study will have access to the data as collected. Any future publications will only include collective information (i.e., aggregate data). Your individual responses (i.e. raw data) will not be shared with anyone outside of the research team. When the research is completed, the researcher/s will keep the data for up to 5 years after the study is over.

INCENTIVE FOR PARTICIPATION:
You will have the option to enter a draw to receive 1 of 3 $100 Visa Gift Cards for your participation in the survey. As noted above, we will need to contact you to notify you if you win, and you can choose your method of notification (email address, mailing address, or phone number).

YOUR RIGHTS AS A RESEARCH PARTICIPANT:
Participation in research is completely voluntary and you can withdraw your consent at any point by closing your browser, *up to* clicking the submit button at the end of the survey. However, because the survey is anonymous, once you click the submit button at the end of the survey the researchers will not be able to determine which survey answers belong to you so your information cannot be withdrawn after that point.

Please note, that by clicking submit at the end of the study you are providing your consent for participation. By consenting to participate you are not waiving any of your legal rights as a research participant.

QUESTIONS?
If you have any questions about this research, please feel free to contact:

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Fax: 416-979-5362 (departmental)

If you have any questions about your rights or treatment as a research participant in this study, please contact the Ryerson University Research Ethics Board at rebchair@ryerson.ca (416) 979-5042.

Appendix D: Survey instrument

INCLUSION CRITERIA:

You are required to be at least 18 years of age to complete this survey. Please confirm this below in order to continue

- Yes, I am at least 18 years of age
- No, I am under the age of 18 (Survey will terminate)

SECTION A: LOCATION

In order to compare your responses to data on noise levels and sound environment characteristics, we require information about your location. Note that this will not be used to identify you and that your information will be stored on a secure database at Ryerson University.

1. What is your postal code?

2. What is your street address? (optional)

SECTION B: NOISE PERCEPTION

3. How pleasurable are the sounds you experience when you are **in your neighbourhood/outside your dwelling**?
   1= very unpleasant, 9=very pleasant

   1 2 3 4 5 6 7 8 9

4. How calming, exciting or stressing are the sounds you experience when you are **in your neighbourhood/outside your dwelling**?
   1= calm, 9=excited/stressed

   1 2 3 4 5 6 7 8 9

5. How stressful does sound **in your neighbourhood/outside your dwelling** make you feel?
   1=not at all, 10=extremely

   1 2 3 4 5 6 7 8 9 10

6. How long (minutes) could you spend in this sound environment before feeling the need to leave?
   <10 10 20 30 40 50 60 70 80 90 100 … > 120

7. Do you want to continue to live in this sound environment?
   1=never, 3=maybe, 5=I would love to

   1 2 3 4 5

8. What thoughts or images come to mind when you experience sound from outside your dwelling? (Optional)

9. Thinking about the last 12 months or so, when you are here at home, how much does outdoor noise bother, disturb or annoy you?
   1= Not at all
   2= Slightly
   3= Moderately
   4= Very
   5= Extremely

10. Thinking about the last 12 month or so, when you are here at home, what number from 0 to 10 best shows how much you are bothered, disturbed or annoyed by outdoor noise?

    0= not at all annoyed; 10= extremely annoyed

11. Thinking about the last 12 months or so, when you are **in your neighbourhood**, how much does outdoor noise bother, disturb or annoy you?
    1= Not at all
    2= Slightly
    3= Moderately
    4= Very
    5= Extremely

12. What is the primary source of outdoor noise at home?

13. Thinking about the last 12 month or so, when you are here at home, what number from 0 to 10 best shows how much you are bothered, disturbed or annoyed by **road traffic** noise?

    0= not at all annoyed; 10= extremely annoyed

14. Thinking about the last 12 months or so, when you are here at home, how much does **road traffic** noise bother, disturb or annoy you?
    1= Not at all
    2= Slightly
    3= Moderately
    4= Very
    5= Extremely

15. Thinking about the last 12 months or so, when you are **in your neighbourhood**, how much does **road traffic** noise bother, disturb or annoy you?
    1= Not at all
    2= Slightly
    3= Moderately
    4= Very
    5= Extremely

16. Would you say you are sensitive to noise?
    1= Not at all
    2= Slightly
    3= Moderately
    4= Very
    5= Extremely

17. Over the past 12 months or so, while you were at home, did outdoor noise never, seldom, sometimes, often or always interfere with your ability to… sleep?
    1. never
    2. seldom
    3. sometimes
    4. often
    5. always
    6. don’t know
    7. Not applicable/refused

18. What is the primary source of noise that interferes with sleeping?

19. Are you currently exposed to loud noise at work?
   - Yes
   - No
   - Don’t know
   - Not applicable/refused

20. Do you have noise-induced hearing loss?
   - Yes
   - No
   - Don’t know
   - Not applicable/refused

21. Do you have any other hearing problems, including but not limited to tinnitus (ear ringing) or presbycusis?
   - Yes
   - No
   - Don’t know
   - Not applicable/refused

SECTION C: HEALTH AND WELLBEING

22. In general, would you say your health is:
   1= Excellent
   2= Very good
   3=Good
   4=Fair
   5=Poor

23. Thinking about the last 12 months or so, how would you say that environmental noise in your neighbourhood has impacted your quality of life?

   -5: very negatively; 0: neutral; 5: Very positively

SECTION E: DEMOGRAPHIC, SOCIOECONOMIC AND HOUSING INFORMATION

24. Is this dwelling in which you live owned by you, a member of this household, or it is rented?
   - Owned
   - rented
   - Don’t know

- Not applicable/refused

25. What type of dwelling do you reside in?
    - Detached
    - Semi-detached
    - Townhouse
    - Low-rise apartment building (less than 5 floors)
    - High-rise apartment building
    - Other (Please specify):____________

26. Does your dwelling need major repairs?
    - yes
    - no
    - don't know
    - Not applicable/refused

27. What is the approximate age of your dwelling construction?

28. Have the windows of your dwelling been updated since the original construction?
    - Yes
    - No
    - Don't know/Refused

29. What type of exterior/siding does your dwelling have on its most noise-exposed façade?
    - Brick
    - Stucco
    - Vinyl siding
    - Fiber-cement
    - Stone
    - Wood
    - Other:_________

30. Is your bedroom located on the most exposure façade of your dwelling?
    - Yes
    - No
    - Don't know/refused

31. On which floor of your dwelling is your bedroom located?

32. In what year were you born?
    - Enter year of birth
    - Don't know
    - Not applicable/refused

33. What gender are you?
   - Female
   - Male
   - Don’t know
   - Not applicable/refused

34. Including yourself, how many people live in your household?
   - Enter number
   - Don’t know
   - Not applicable/refused

35. How many members of your household are 18 years old or younger?
   - Number
   - Don’t know
   - Not applicable/refused

36. What is the highest level of education you have completed?
   - Less than high school
   - Completed high school or equivalent
   - Completed post-secondary school
   - Don’t know
   - Not applicable/refused

37. What is your employment status?
   - Full-time job
   - Part-time job
   - Unemployed
   - Retired
   - Homemaker
   - Student (includes students working part-time)
   - Other (specify)
   - Don’t know
   - Not applicable/refused

38. Could you please tell us how much **total** income you and other members of your household received in 2016? We don't need the exact amount; could you tell us which of these broad categories it falls into?

   - ...less than $25,000
   - ...between $25,000 and $50,000
   - ...between $50,000 and $75,000
   - ...between $75,000 and $100,000
   - ...more than $100,000

- …Don’t know
- ...Not applicable/refused

Thank you for your participation in this study. If you will like to be entered into the gift certificate draws, please provide us with your preferred method of contact. If you do not provide a method of contact we cannot enter you into a prize draw.

- Mailing address
- Email
- Telephone Number

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