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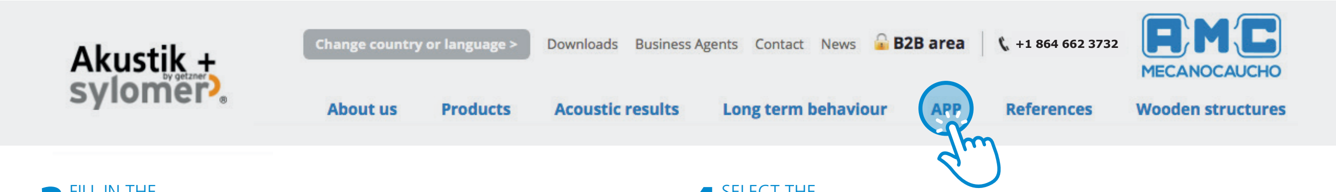

2 FILL IN THE **INPUT DATA**

Indicate if you want to isolate a floor or a ceiling. Then introduce the weight per square meter and distance between hangers/ mounts.

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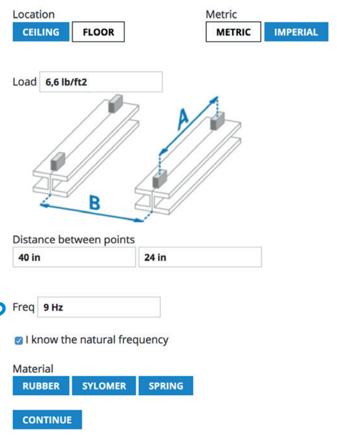
Introduce the natural frequency that you require. If you ignore this value you can select if your preference is high isolation or cost effectiveness. You can also select if the elastic material is rubber, Sylomer or spring.



Location: CEILING | FLOOR

Metric: METRIC | IMPERIAL

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Distance between points: 40 in | 24 in

Freq: 9 Hz

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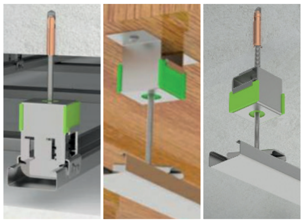
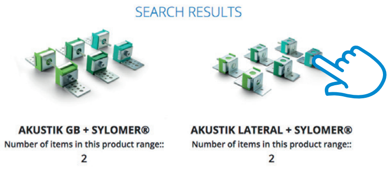
Finally select the hanger that suits best.



Straight to profile | Straight to slab | Between threaded rods



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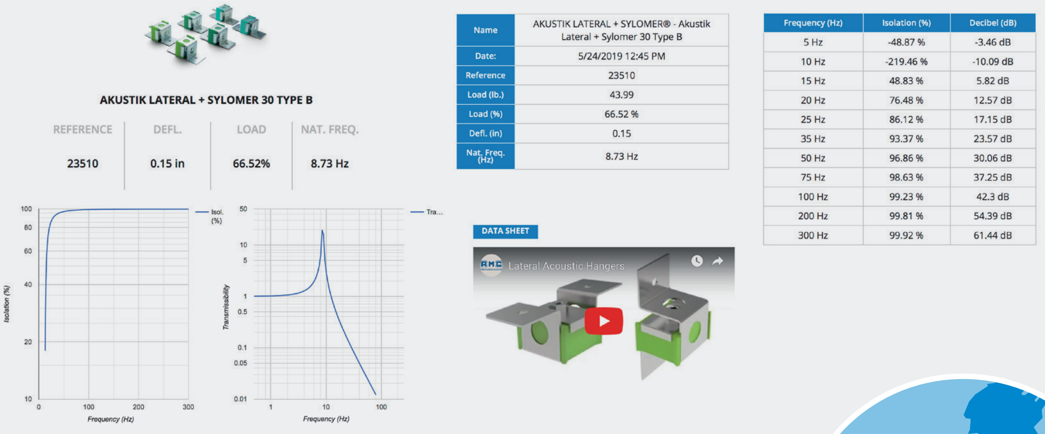

AKUSTIK LATERAL + SYLOMER 30 TYPE B

REFERENCE	DEFL.	LOAD	NAT. FREQ.
23510	0.15 in	66.52%	8.73 Hz

Name	AKUSTIK LATERAL + SYLOMER® - Akustik Lateral + Sylomer 30 Type B
Date:	5/24/2019 12:45 PM
Reference	23510
Load (lb.)	43.99
Load (%)	66.52 %
Defl. (in)	0.15
Nat. Freq. (Hz)	8.73 Hz

Frequency (Hz)	Isolation (%)	Decibel (dB)
5 Hz	-48.87 %	-3.46 dB
10 Hz	-219.46 %	-10.09 dB
15 Hz	48.83 %	5.82 dB
20 Hz	76.48 %	12.57 dB
25 Hz	86.12 %	17.15 dB
35 Hz	93.37 %	23.57 dB
50 Hz	96.86 %	30.06 dB
75 Hz	98.63 %	37.25 dB
100 Hz	99.23 %	42.3 dB
200 Hz	99.81 %	54.39 dB
300 Hz	99.92 %	61.44 dB

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NEIGHBOURHOOD CONTEXT AND COMPOSITION MODERATE THE NOISE ANNOYANCE DOSE-RESPONSE

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Résumé

La croissance de la population urbaine, les conflits d'utilisation des sols et l'augmentation du trafic aggravent la pollution sonore dans les zones urbaines. Toronto est l'une des villes qui doit relever un défi en luttant contre le bruit ambiant. L'importance de cette recherche repose sur une absence relative de littérature sur la manière dont la sensibilité au bruit et la gêne sont affectées par des facteurs non acoustiques, tels que les constructions environnantes, la démographie et les facteurs socio-économiques. Les données d'une enquête sur le bruit dans les quartiers (n=552) en 2017 ont été combinées avec des données spatiales sur les constructions environnantes et les expositions au bruit prévues. L'analyse bivariée et la régression multivariée ont montré que les facteurs socio-économiques et d'environnement physique influencent les réponses de nuisance sonore. Plus précisément, les résidents d'un quartier au statut socio-économique élevé et ayant accès à des espaces verts, et dont le niveau de bruit nocturne est faible, étaient plus de deux fois plus susceptibles (rapport de cotes : 2,35 ; p<0,001) de signaler une gêne élevée lors de l'évaluation du paysage sonore du quartier par rapport aux résidents de quartiers au statut socio-économique modéré et ayant un accès plus faible à des espaces verts. Bien que les niveaux de bruit nocturnes semblent être un prédicteur important des différences entre les quartiers en termes de nuisances sonores à la maison et dans le voisinage, les résultats montrent que les perceptions du bruit sont déterminées en partie par les contextes des quartiers, tels que la qualité de l'environnement et les caractéristiques individuelles. Pour les futures recherches sur la perception du bruit, les résultats justifient la prise en compte explicite des perceptions communes des quartiers en matière de bruit et d'attentes environnementales.

Mots clefs : Paysage sonore, bruit environnementale, perception du bruit, nuisance sonore, sensibilité au bruit, qualité de vie.

Abstract

Growing urban populations, conflicting land uses, and more traffic are exaggerating noise pollution in urban areas. 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 the built environment and predicted noise exposures. Bivariate analysis and multivariate regression showed that socioeconomic and physical environment factors influence the noise annoyance responses. Specifically, residents in a neighborhood with high socioeconomic status and access to green space, and low night time noise levels, were more than twice as likely (Odds Ratio:2.35; p<0.001) to report high annoyance when evaluating the neighbourhood soundscape relative to residents of neighbourhoods with moderate socio-economic status and lower access to green space. Although nighttime noise levels appeared to be a strong predictor of neighbourhood differences in noise annoyance at home and in the neighbourhood, the findings demonstrate that noise perceptions are determined in part by neighbourhood contexts such as environmental quality and individual characteristics. For future research on noise perception the results warrant explicit consideration of shared neighbourhood perceptions of noise and environmental expectations.

Keywords: Soundscape; environmental noise; noise perception; noise annoyance; noise sensitivity; quality of life.

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1 Introduction

The most common effects of environmental noise exposure are noise annoyance and sleep disturbance [1-4]. Annoyance is used and promoted as a metric to guide policy development, but it is also a challenging metric to use because of its subjective nature [5, 6]. To this end, this study helps clarify what types of individual (composition) and environmental (context) characteristics affect levels of noise annoyance. Advancing knowledge on environmental noise effects is crucial to support the development of policies and reduce harmful effects of noise. It is an important challenge with a global scope: 125 million Europeans are exposed to levels of road traffic noise above those recommended by the World Health Organization, and noise is the most significant health threat after air pollution [7]; 40% of Australians are exposed to

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harmful levels of traffic noise [8]; noise pollution is a foremost quality of life problem in New York City [9]; In Toronto, noise complaints increased by 312% for the period 2009-2015 [10]. Although the EU Noise Directive as well as national and local regulations around the world are good examples of progress, these are scattered efforts and within North America do not appear to have any notable impacts on reducing exposures.

Noise annoyance can be considered a health outcome of noise exposure but has more traditionally been considered as an indicator of wellbeing or a moderator of adverse health outcomes [11]. Noise annoyance is associated with disturbance, unpleasantness, and anger and can lead to aggressive behavior, fatigue, and negative emotions [12-14]. Other health effects include increased stress and associated effects on the cardiovascular system [15, 16], reduced cognitive performance among students [17], and general impairment of cognition and reduced mental health [18]. Laboratory-based experimental research on the effects of sounds on humans confirm the relationship between neuroendocrine responses and auditory stimuli [19]. Although biomedical research on noise has contributed to the current understanding of adverse health effects, there is still a limited understanding of how individual experiences modify these health effects [20].

There is a long history of research trying to understand the relationship between noise exposures and noise perception [21-24]. However, progress is challenged by the use of different metrics and methods for noise exposure assessment, as well as inconsistent measurements of noise annoyance and sensitivity. Although the equivalent sound pressure level (Leq) is the predominant predictor variable of annoyance, this method is not entirely satisfactory because annoyance has long been understood to be a strongly subjective factor [25]. It is not clear how noise sensitivity affects annoyance or how sensitivity is affected by acoustic or non-acoustic factors [26, 27]. Sensitivity may also be a group characteristic as Schomer et al. [26] found that different communities exposed to the same level of noise can exhibit varying levels of annoyance. Nonetheless, both acoustic and non-acoustic factors such as socio-economic status and attitudinal variables influence noise annoyance [28, 29]. Soundscape research on tranquility shows that in addition to noise levels, the presence of certain sound sources and visual elements are influential [30]. Taken together, these findings show that characteristics of sound (e.g. tone, temporal structure, and spectrum, etc.), individual characteristics (e.g. health, age, noise sensitivity), and socio-economic factors all play a role [13, 26, 31].

Built form and architectural design, arrangement, existence of open spaces, absorption characteristics of building materials, and shape can influence noise levels and perceptions. Silva et al. [32] examined ten types of built form and found that historic urban forms with their characteristics such as narrow streets, complex road networks, medium building height, and numerous intersections 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 generally produce higher levels of traffic noise [33]. Traffic noise is associated with a stressful sound environment and is one of the most clearly established predictors of annoyance. However, other types of transportation noise as well point sources of noise are also strong predictors of annoyance. This includes railway noise characterized by rail squeals and screeching as well as vibration. Licitra et al. [34] suggest that the effects of these sources can be underestimated in urban areas because they represent relatively high noise peaks and deviations from background levels. Interestingly, results of aggregated noise surveys show that the Ldn dose-response curve is flatter for railway noise and steeper for air traffic when compared to traffic noise, though these results do not consider the effects of noise peaks [23].

Conversely, sounds that signal a human presence like footsteps and voices along with natural sounds (e.g. bird song) are associated with a relaxing, positive sound environment [35, 36]. Echevarria Sanchez et al. [37] showed that geometrical street designs can reduce the street canyon effect and therefore, reduce negative noise perceptions for pedestrians and other affected population. To this end, vegetation can also be effective in absorbing and scattering sounds [38, 39]. Green space and vegetation are associated with reducing negative perceptions of sound, and therefore reducing noise annoyance [40, 41]. Furthermore, there is extensive literature showing the importance of green space and vegetation as therapeutic landscapes that contribute to physical and mental health and wellbeing [39, 42-44] .

There are multiple pathways between urban green space and health, including noise and air pollution buffering and reduced cardiovascular morbidity [39]. With such a profound effect on human health it can be expected that green space and vegetation are factors that influence noise annoyance. This study uses a novel study design to examine the influence of neighbourhood context and individual characteristics on noise perception. Binomial logistic regression modeling was utilized to examine the demographic, socio-economic, and health characteristics along with the built environment contribute to noise annoyance among residents in three distinct neighbourhoods of Toronto, Ontario, Canada.

2 Methods

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 km2 and has a population of 2.7 million [45]. 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 forms 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 and mixed land uses outside of the downtown. The study focused on three neighbourhoods located in the central business district, inner and outer suburbs of the city: (1) Trinity-Bellwoods, (2) Church-Yonge and Bay Corridor (referred to as Downtown), and (3) Banbury - Don Mills (referred to as Don Valley) (Figure 1). The three neighbourhoods were chosen to represent the diversity of built forms and environments commonly found in Toronto and other North American cities.

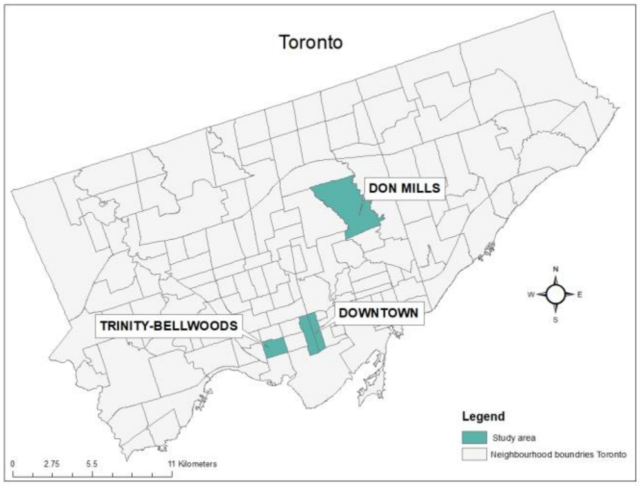

Figure 1: Location of neighbourhood study areas within the City of Toronto

Trinity-Bellwoods is an inner-city middle density neighbourhood where most residents live in semi-detached houses. The Downtown neighbourhood is adjacent to the central business district in the city, with mixed residential and commercial buildings of high density. Most of the residents live in high-rise condominiums, but fringes of the neighbourhood include low-rise buildings, detached and semi-detached houses. The Don Valley neighbourhood (Banbury - Don Mills) is a suburb originally developed as a master-planned community outside previous city boundaries with low density and high socioeconomic status. The majority of this area is residential with detached houses and a relatively dense tree canopy.

2.2 Neighbourhood noise survey

Residents were recruited by postcard invitations to complete an online survey instrument. Distribution of the postcards took place in July 2017, with approval of the recruitment and consent method as well as the survey instrument from the Ryerson University Research Ethics Board. Approximately 2000 households were targeted in each of the 3 neighbourhoods of interest. Survey participant addresses were georeferenced and linked to noise metrics to characterize their exposures. The survey was designed using ISO/TS 15666:2003 standard questions for assessment of environmental noise annoyance based on two questions: (1) Verbal rating scale with five answer options to the question “Thinking about the last 12 months or so, when you are here at home, how much does outdoor noise bother, disturb or annoy you?”: “Not at all?; Slightly?; Moderately?; Very?; Extremely?” and (2) Numerical rating scale with 11 answer options 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]?” [46]. 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. Questions on demographic and socioeconomic information were also included.

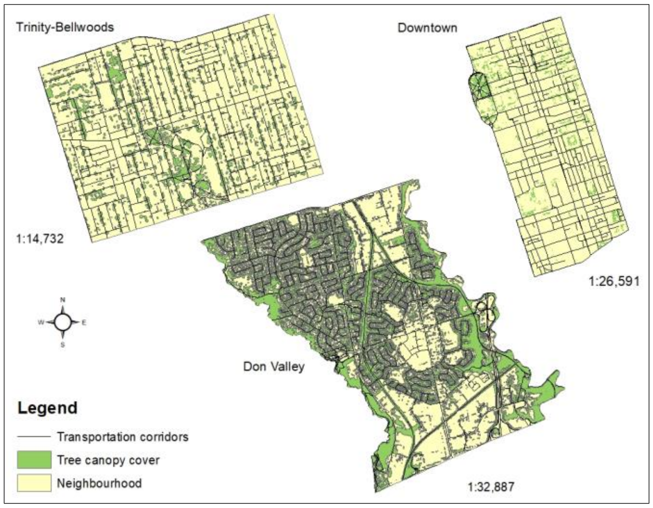

Figure 2: Sampling areas, road network, and tree canopy cover in the three neighbourhoods

2.3 Built environment and noise exposure variables

Noise data was collected during the summer of 2016 from 220 locations throughout Toronto. The sampling sites covered the entire city and were selected randomly or 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 Type 2 Noise Sentry RT sound level meter data logger (Convergence Instruments, Sherbrook, QC, Canada) at a sampling rate of 4 Hz and data integration of 1 Hz (Leq an LMax). Post-processing of data allowed development of all relevant metrics such as daytime, evening, nighttime, weekday, weekend, and weighted 24-hour equivalent sound pressure levels. Details on monitoring, modelling and model validation are described in Oiamo et al. [47].

In brief, two types of environmental noise models were developed and used for exposure assessment in the current study. This included (1) a traffic noise propagation model based on the United States Federal Highway Administration Traffic Noise Model (TNM2.5) standard assessed at building facades (Traffic (24h)), and (2) hybrid traffic noise propagation and land use regression models to represent total environmental noise, assessed at building facades (façade level Day/Night/24h) and street centrelines in front of respondent residences (street level Day/Night/24h). City of Toronto traffic survey data represented as the annual average daily traffic (AADT) volume of vehicles on all city streets were used in the traffic noise propagation model. Standardized traffic histograms were used to distribute AADTs by type of vehicle (light, medium and heavy), by time of day and for different road types. The propagation model included topography and three-dimensional building representations as it is well known that buildings can have a strong effect on sound acoustics [32]. The façade noise assessments were based on estimated levels on the loudest building façade. Noise exposures were categorized according to the lower threshold recommended by the WHO at 55dBA and 10 dB intervals [48]. Variables to represent neighbourhood greenspace and natural areas included the linear distance to the nearest part or natural area, tree canopy cover within 200m and 500m buffers, and area of parks within 200m and 500m buffers. Tree canopy cover was calculated from high resolution land cover data (30 cm) from the City of Toronto Open Data Catalogue. The buffers were chosen to correspond with WHO findings on health benefits of parks and green space within a 5 minute or maximum 15-minute walk [49]. The tree canopy cover around each participant's residence was divided into quartiles that represent the same number of residents exposed to each level of tree canopy near their residence and within each neighbourhood.

2.4 Analysis

Logistic regression is a commonly applied approach in socio-acoustic studies, where there is a mixed use of continuous and categorical variables. Logistic regression models can accommodate both categorical and continuous variables as predictors to understand their effect on a binary outcome variable, which in this case was to predict high levels of noise annoyance (HA) at home and in the neighbourhood. The final models included the following variables: Model 1 tested the differences in the three neighbourhoods; Model 2 added the demographic variables age and sex; Model 3 tested the effect of the socio-economic factors housing tenure (ownership), educational attainment (high school vs. post-secondary), and employment status (full-time vs. part-time/unemployment and student/ homemaker/ retiree); Model 4 controlled for noise sensitivity, self-reported general health status, and hearing problems; Model 5 controlled for neighbourhood greenspace as measured by tree canopy cover, and; Model 6a, 6b, and 6c tested the influence of day and night total noise levels and 24-hour traffic noise levels, respectively. The odds ratios (OR) estimated by the logistic regression are reported to represent the relationship between predictors and high annoyance at home and in the neighbourhood. All data processing and analyses were done with SPSS 24 (IBM, Armonk, NY, USA) and ArcGIS 10.4 (ESRI, Redlands, CA, USA).

3 Results

3.1 Sample characteristics & bivariate analysis

The study recruited 552 participants and the response rate based on the number of distributed postcards was 9%. The response rate in Downtown was higher than the other neighbourhoods and represented 66% of the sample (Table 1). The highest proportion of respondents in Trinity-Bellwoods were in the age category 35-54, while participants Downtown were predominantly aged 18-34 and 35-54. In Don Valley, most respondents were aged 55-75 (66%). The Downtown sub-sample had a higher proportion of males (60%) compared to Trinity-Bellwoods (63% female) and Don Valley (56% female). The proportion of respondents reporting their occupational status as full-time or self-employed ranged from 42% to 62%, while the remaining respondents reported a mix of different statuses, such as homemaker, retired, and student. However, a large proportion of respondents in Don Valley were retired and homemakers (45.9%). In all three neighbourhoods a high proportion of respondents had completed post-secondary schooling (87-89%) and reported a good or very good level of general health (36-43%).

Most residents Downtown rented their property (62%) but the reverse was the case for Trinity-Bellwoods (37%) and Don Valley (15%). Most participants in Trinity-Bellwoods lived in semi-detached houses, while 53% of Downtown participants lived in high-rise building, and the majority of residents in Don Valley lived in detached houses (72%). A lower proportion of the Downtown sub-sample reported being very sensitive to noise, but this difference was not significant (Table 1). Likewise, there were varying but non-significant differences in the proportion of residents reporting high noise annoyance at home. Conversely, there were significant differences in levels of high noise annoyance while in the neighbourhood around participant residences, with the highest percentages observed in Don Valley (36.5%) and Downtown (35.8%), compared to 20.4% in Trinity-Bellwoods. The noise exposure assessment showed that participants were exposed to façade daytime noise levels between 55-65 dB (Table 2). However, average façade levels at night in the Downtown study area was above the threshold of 55 dB, while participants in the other two neighbourhoods were below this threshold. Chi-square tests showed significant neighbourhood differences in the proportion of residents exposed to high levels of noise.

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

3.2 Logistic regression on high annoyance at home

The regression models were based on self-reported levels of high annoyance (HA) as measured by the question "Thinking about the last 12 months or so, when you are here at home, how much does outdoor noise bother, disturb or annoy you?"

Table 1: Descriptive table of categorical variables and chi-squared tests for differences between the three neighbourhoods.

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

Table 2: Descriptive table of categorical variables of noise (dB) and chi-squared tests for differences between the three neighbourhoods.

		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
	55 – 65	52.9	77.6	43.4	65.9	(0.000)
	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
	55- 65	28.8	12.2	35.5	18.8	(0.000)
	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
	55 – 65	48.2	52.0	45.0	57.6	(0.000)
	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
	55 – 65	34.4	16.3	45.5	7.1	(0.000)
	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
	55 - 65	55.6	81.6	44.2	75.3	(0.000)
	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
	55 – 65	58.5	83.7	46.6	81.2	(0.000)
	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
	55 – 65	28.8	16.3	31.2	32.9	(0.000)
	65 – 75	26.3	3.1	36.0	10.6	
	75 dB+	0.2	0.0	0.3	0.0	

Model 1 showed that without controlling for other covariates, residents in Downtown were 2.17 (p<0.01) times more likely to report high annoyance than residents in the Trinity-Bellwoods reference neighbourhood (Table 5). Compared to the age group 18-35, respondents aged 35-54 and 55-74 were significantly more likely to report HA. When controlling for socio-economic factors it was observed that homeowners were 1.90 (p<0.01) times more likely to report high annoyance at home, compared with people that rent their homes. Model 4 showed that people with high noise sensitivity were5.96 (p<0.001) times more likely to be highly annoyed than participants reporting no or low levels of noise sensitivity. Those who reported being somewhat sensitive had a 2.73 (p<0.001) higher likelihood of reporting high annoyance. When controlling for green space it was observed that participants with moderately low access to green space (3rd quartile) were 2.14 (p<0.01) times more likely to be highly annoyed when they are at home compared to those with high access to green space (4th quartile).

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

			Full Sample			Anova 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 500 m variable split into 4 quartiles for each of the three neighbourhoods.

Tree Canopy Cover (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+

The effects of different noise variables on HA were tested separately in Model 6. The results showed that there was no significant effect on noise annoyance at home from daytime or 24-hour noise levels. However, nighttime noise levels were a significant predictor for HA. Residents exposed to levels between 55 to 65 dB were 2.76 ($p<0.01$) times more likely to be highly annoyed than those exposed to levels below 55 dB. Those exposed to levels above 75 dB were 3.78 ($p<0.01$) times more likely to report high annoyance. When controlling for nighttime noise levels the effect of residing in the Downtown neighbourhood disappeared and the effect of tree canopy cover was reduced.

3.3 Logistic regression on high annoyance in the neighborhood

Interesting differences were observed for HA at home versus in the neighbourhood. Residents in both Downtow and Don Valley sub-samples were 2.39 ($p<0.01$) and 2.55 ($p<0.05$) more likely to report HA in the neighbourhood than participants in Trinity-Bellwoods (Table 6). However, the effects of residing in Don Valley disappeared in Model 2, suggesting that differences in neighbourhood demographics influenced responses to environmental noise. Similar to the logistic regression analysis of high annoyance at home, respondents aged 35-74 and with high noise sensitivity were also more likely to report high annoyance in the neighbourhood. Tree canopy cover was significant 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 Don Valley had an increased likelihood of high annoyance 2.31 ($p<0.05$) times higher than Trinity-Bellwoods. The significance of Don Valley remained when con-

Table 5: Logistic regression model odds ratios for effects on noise annoyance at home.

Parameter estimates	FULL SAMPLE							
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6a Lday	Model 6b Lnight	Model 6c L24h
(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: Owner)*			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: Q4)*						*	*	*
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)*							*	
55-65 dB						2.75	2.76**	2.30
65-75 dB						2.03	2.20*	1.75
>75 dB						2.62	3.78**	2.29
Hosmer & Lemeshow $\chi 2$ (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

trolling for each noise variable.

The results from the logistic regression model on high annoyance in the neighbourhood showed that nighttime noise levels were still a strong predictor for high annoyance. Residents exposed to 55 to 65 dB were 2.35 (p<0.05) times more likely to report high annoyance compared with those exposed to below 55 dB. Furthermore, when controlling for nighttime noise levels the effect 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 – 65 dB were 5.97 (p<0.05) times more likely to report high annoyance compared to those exposed to below 55 dB. Furthermore, those exposed to 65-75 dB were 6.29 (p<0.05) times more likely to be highly annoyed. Removing the neighbourhood covariate increased the effect of noise, but did not change the effect of other covariates.

Table 6: Logistic regression model odds ratios for effects on noise annoyance in the neighbourhood.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6a Lday	Model 6b Lnight	Model 6c L24h
(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)*								
55-65 dB						5.35	2.35*	5.97*
65-75 dB						5.84	2.10*	6.29*
> 75 dB						5.02	2.16	5.12
Hosmer & Lemeshow $\chi2$ (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

4 Discussion

The goal of this study was to better understand levels of noise annoyance and its distribution in Toronto, the role of neighbourhood context and composition versus environmental noise exposures. Michaud et al. [5] reported that 6.7% of all participants in a national survey in Canada were highly annoyed by road traffic noise. This study found that 32% of the full sample reported high noise annoyance. Interestingly, participants in Downtown and Don Valley had similar levels of noise annoyance despite notable differences in noise exposure. This confirmed that noise exposure cannot solely predict noise annoyance. This study found that other predictors of noise annoyance include socioeconomic characteristics, the built environment, green space, noise sensitivity and nighttime noise levels. Our findings also suggest that nighttime noise is an important predictor of noise annoyance even among people that may be 'desensitized' by living in noisy environments.

Noise sensitivity in the Downtown neighbourhood (18%) was lower than the other two neighbourhoods. In Downtown Toronto, gentrification and attraction to a central location are strong influences on residential preference. Naturally, central locations are associated with higher noise levels due to a high concentration of commercial, and cultural and recreational activities [29]. It is unclear whether lower sensitivity reduces vulnerability to adverse health effects from noise, but this study showed that despite the relatively low level of noise sensitivity in Downtown Toronto, residents of this neighbourhood were still highly annoyed by traffic noise. Considering noise annoyance as a stress response that can lead to more severe health outcomes, our findings further compels the targeted reduction of nighttime noise as a priority for reducing adverse health outcomes. Noise sensitivity has been largely ignored in various epidemiological and biomedical research on noise and health due to its complexity as a non-unified concept [31, 50, 51]. Nevertheless, several studies have investigated the relationship of noise sensitivity and health [1, 52-54]. Shepherd et al. [54] investigated the relationship between environmental noise and health-related quality of life (HRQOL) in Auckland, New Zealand and found that annoyance and sleep disruption are mediators of noise sensitivity. As such, noise annoyance and sensitivity might degrade HRQOL and compromise sustainable development during the unprecedented growth and densification of Toronto and cities undergoing similar transformations elsewhere.

Observed differences in neighbourhood sensitivity may be partially attributed to differences in built form and residential densities in the study neighbourhoods [33, 37, 41]. The Downtown area is associated with more constant background noise from commercial traffic, large HVAC systems and entertainment activities, which are exaggerated by the street canyon effect of dense and high-rise buildings [55]. In contrast, Don Valley's built form is predominantly low density residential, lacking the "hum" of the busy Downtown streets. Detached and low-density housing combined with more tree canopy cover creates a different sonic and visual environment in Don Valley, further differentiated by different noise sources such as landscaping equipment, residential HVAC, and other machinery. In this environment, peak noise events such as emergency vehicles or air traffic are more noticeable. The reaction to these peak noise events may contribute to elevated noise annoyance and higher sensitivity, despite the relatively low noise levels. Further, factors such as the type of buildings and the quality of their envelope, infrastructure, 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 [51] suggest that noise sensitivity might be related to a general environmental dissatisfaction and greater concern for environmental problems. The Don Valley neighbourhood can be characterized as a neighbourhood with high environmental quality (e.g. access to green space; low crime). This study suggests that expectations of environmental quality rather than a general environmental dissatisfaction can moderate noise perceptions in high-income neighbourhoods. Access to greenspace and tree canopy cover are often associated with higher property values [56-58]. Although access to greenspace did not correspond to lower annoyance between neighbourhoods, we observed that lower tree canopy cover within neighbourhoods increased the likelihood of noise annoyance. Gidlöf-Gunnarsson and Öhrström, [59] found that greater availability to green space of residents of Stockholm was related to reduced long-term noise annoyance. Our study confirms these results within neighbourhoods in Toronto, but also shows that overall neighbourhood levels of noise annoyance are subject to group perceptions. The findings in this study suggest that there is a threshold of green space above which people develop an expectation of the environment and are more likely to exhibit noise sensitivity report high annoyance from noise.

Previous research shows that annoyance is reduced in environments where expectations are congruent with the observed soundscape. Using noise surveys and subjective appraisals of three urban parks in Naples, Italy, Brambilla and Maffei [60] observed that participants' expectations of a particular soundscape in a specific environment influences their annoyance. To this end, the use of equivalent sound pressure level metrics may conceal nuanced differences between soundscapes that influence annoyance. Although equivalent sound pressure levels are the most common noise metrics, their use has been criticized because of the limitation on exposure assessment [61-63]. Equivalent sound pressure levels provide information on loudness, but do not identify different types of sound, which may lead to an incomplete understanding what type of noise exposure a community is experiencing [26]. Factors such as irregular intervals of sound exposures and distinct sounds can affect individuals' noise perception.

5 Conclusion

This study observed alarmingly high levels of noise annoyance in three differing neighbourhoods of Toronto, levels of annoyance that far exceed national trends in Canada [64]. While we observed a significant effect of nighttime noise levels, we also observed high levels of noise annoyance in a neighborhood with high income and access to green space, and relatively low nighttime noise levels, likely influenced by individual soundscape expectations. Extending previous research, the findings suggest that high environmental quality might be related to high expectations for quietness. The study was limited by use of the loudness noise metric, as well as sample size and potential self-selection bias among participants. Nonetheless, the results warrant explicit consideration of shared neighbourhood perception of noise and environmental expectations in future research on noise perception. None of the neighbourhoods in the current study were located near airports or flightpaths, or contained railways, and since noise exposures were limited to sound pressure levels the study was not able to consider the potential effects of noise source mixture and diversity. Future research should therefore also focus on understanding how these factors may affect shared neighbourhood perceptions of environmental noise

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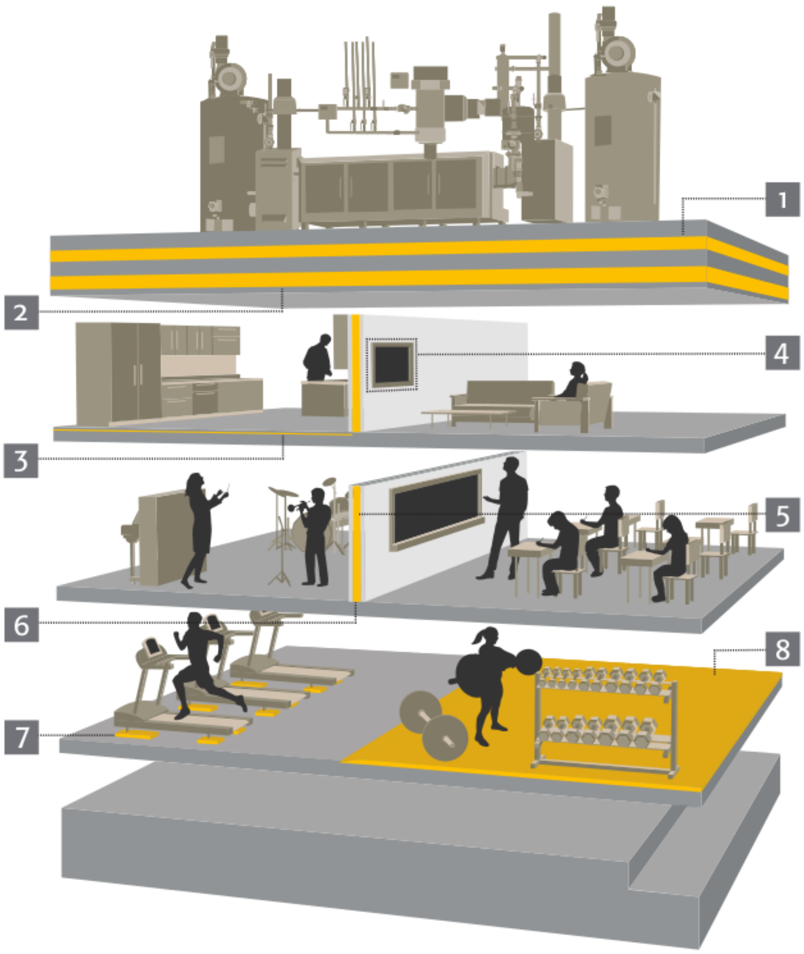
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