A 2-year longitudinal study on noise annoyance related to the construction of a major highway infrastructure

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ABSTRACT

Few studies have been conducted regarding construction noise annoyance. This paper presents the results of the first two years of a longitudinal study aimed to examine noise annoyance related to a road construction project.

1,409 subjects participated in the study in the first year and 855 of them were followed in the second year. Participants were divided in two groups (target and control) based on the distance of their dwelling to the construction sites. They responded to a socio-acoustic survey.

Noise levels between surveys remained stable ($p > .05$). Overall construction noise annoyance remained similar across the study. However, when looking at annoyance levels specifically by period of day, higher annoyance was reported in the second year for both groups ($p < .001$). Sleep disturbance from construction noise increased from 23 to 30% in the target group and from 6 to 20% in the control group.

To avoid missing any variation in annoyance, time periods should be taken into account in socio-acoustic surveys regarding construction noise.

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INTRODUCTION

Environmental noise can affect health. It is associated with annoyance, sleep disorders, cardiovascular problems and communication problems [1]. The World Health Organization (WHO) considers environmental noise one of the most disturbing challenges to the quality of life and human health [2]. Traffic noise has been shown to hinder the largest proportion of respondents in a large socio-acoustic survey conducted in Canada [3]. Construction noise can also affect a significant proportion of the population. In one study, around 4.6% of the respondents reported being highly annoyed by construction noise [4]. But, when investigating noise annoyance specifically to the construction of a large metropolitan highway complex, our research team has shown that this proportion can reach up to 28.0% in participants living less than 300 m from the infrastructures [5]. While a recent review article concluded that few research have shown an association between annoyance scores and noise levels from construction work [6], previous work from our research team has demonstrated that noise levels explain a marginal variance in annoyance levels (less than 1%). Socio-demographic, psychosocial and contextual factors explained a much larger proportion of the variance (between 51.7 and 70.0%). [5]. In this paper, we present the first longitudinal data (year 1 and 2) obtained in a 4-year study. We aimed at investigating how construction noise annoyance levels differ over time.

METHODS

Study area

The Turcot complex is a highway interchange located in the city of Montreal, in the province of Quebec, Canada, through which almost 300,000 vehicles pass daily. This complex constitutes a significant link between downtown Montreal, Montreal's international airport, the other provinces of Canada and northeastern states of the U.S.A. Studies revealed that the infrastructures that include the Turcot complex need major rehabilitation work. The demolition and reconstruction of this large highway began in 2016. It should be noted that rehabilitation work was performed during all periods of day (i.e., day, evening and night-time periods).

Participants and groups

The target group consisted of participants whose dwelling was located within 300 meters of the Turcot interchange structures. A control group was also set up with participants for whom the distance was between 300 and 1,000 m. These intervals were based on previous findings taken from an environmental impact assessment made in 2008 [7]. The inclusion criteria used to recruit participants were as follows: 1) be over 18 years of age and 2) reside for at least 6 months prior to the date of the interview (tenant or owner) at the sites selected for the survey. Figure 1 shows the Turcot complex structures, which comprises four interchanges, and the area of the study zone (<300 m and between 300 and 1,000 m). The location of the 18 autonomous noise stations used to collect noise level data are also displayed.

In the first year of the longitudinal study (2018), 1409 residents participated in the study, while this number was of 855 in the second year (2019). Figure 2 shows the selection process for the study (for a full review of the initial selection process, see Pinsonnault-Skvarenina et al., 2021) [5]. In the first year, 483 participants were included in the target group and 926 in the control group, while this number was of 301 and 554 respectively in the second year. Participants were divided according to their area of study (based on their home address). Those who initially participated in the first survey (2018) were invited to participate in the second survey (2019). Each participant was given a unique identifier number in order to maintain confidentiality regarding his or her responses.

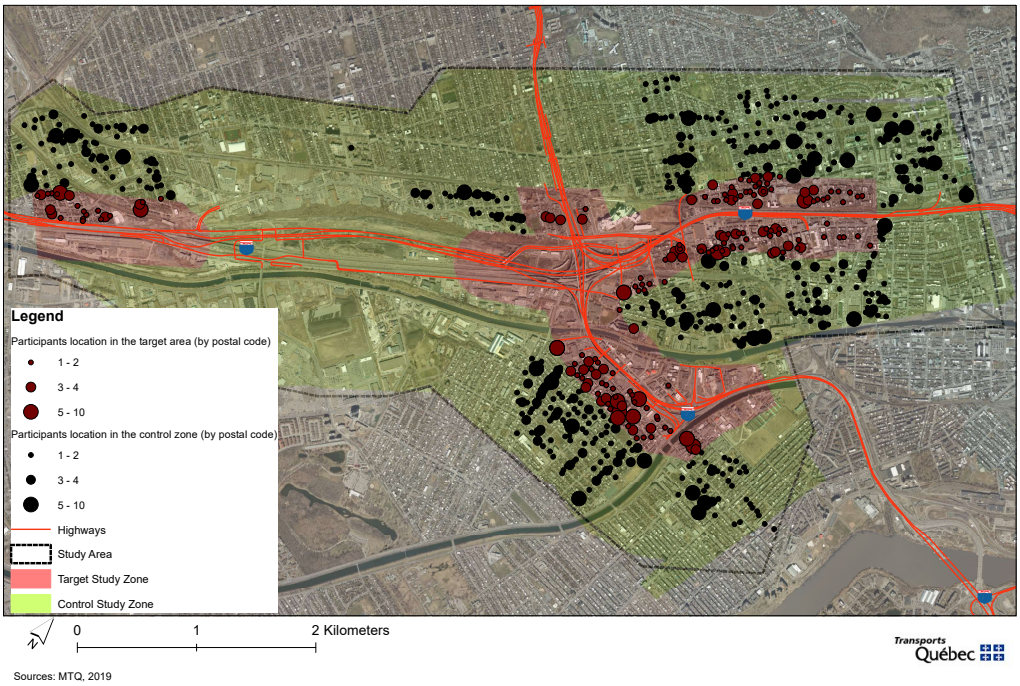

Figure 1: Turcot complex and participants' distribution in the first survey (2019)

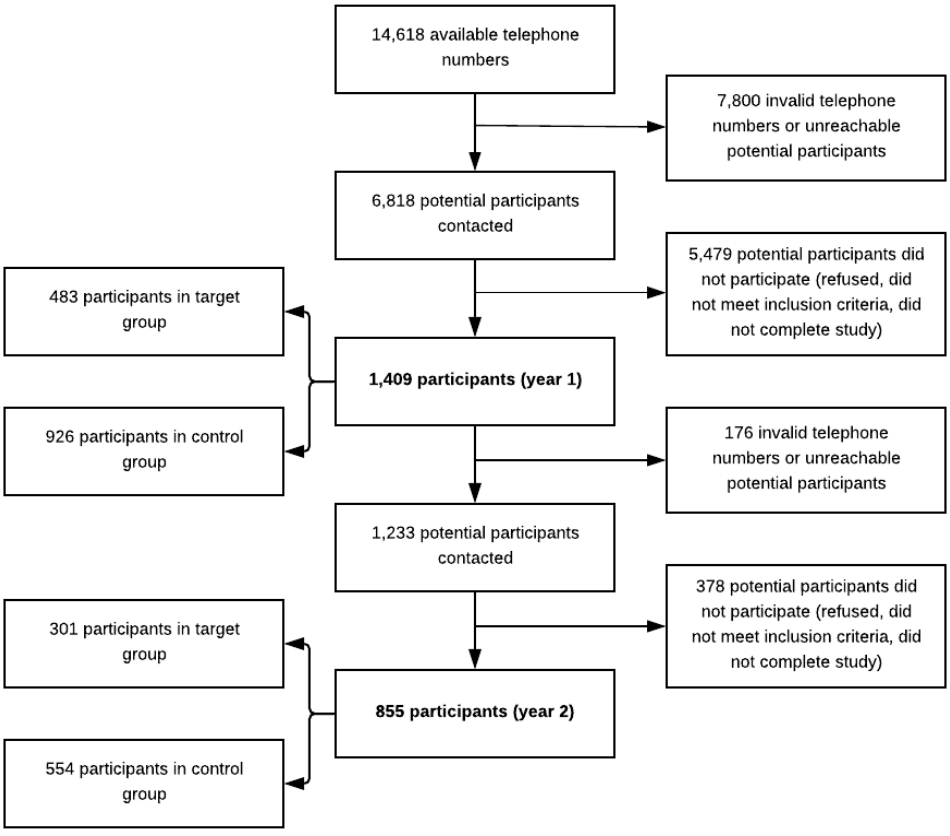

Figure 2: Flowchart detailing the attrition of participants in the study (2018 and 2019)

Noise levels

A total of 18 autonomous continuous noise measurement stations were installed across the study zone (see Fig. 1). The stations were all located within 50 m of the Turcot complex. Noise levels data were measured, and collected in real time, by a class 1 sound level meter consistent with current standards (ISO 1996-1, 2016) [8]. Each station was set away from any obstacles and was mounted sufficiently high from the ground to ensure adequate measurement of the sound level.

The noise stations allowed for the measurements of various noise level indicators (L_{Aeq24h}, L_{Day}, $L_{Evening}$, L_{Night} and L_{10}), based on 30 min time averaging. Periods of the day were identified as follow: 1) L_{Day} – 6:01AM to 7:00PM, 2) $L_{Evening}$ – 7:01PM to 11:00PM and 3) L_{Night} – 11:01PM to 6:00AM. Annual noise levels at each station were calculated.

Questionnaire

A perception survey questionnaire was developed in accordance with the international standard ISO / TS 15666 (2003) [9]. The questionnaires were administered by telephone or online. The survey consisted of six sections designed to collect:

1) characteristics of the housing and the time spent at the residence;
2) sleeping habits of the respondent; including the short version of the Sleep Condition Indicator (SCI), non-specific to the Turcot's construction noise [10];
3) evaluation of the living environment by the respondent;
4) the respondent's opinion of specific noise sources;
5) more specific opinion of the respondent on the noise and other aspects generated by the rehabilitation work of the Turcot complex and on its effects on daily activities and quality of life;
6) characteristics of the respondent (age, gender, educational level, family income, etc.), including the short version of the self-report measure of noise sensitivity developed by Benfield and al. (2014) [11].

The question relating to annoyance, prescribed by the international standard ISO/TS-15666 (2003) [9], was the following: "Thinking about the last year or so, when you are here at home, how much does noise from (NOISE SOURCE) bother, disturb or annoy you?". The response scale ranging from zero to ten was converted to annoyance categories. A rating between 0 and 2 indicates that the respondent reported they are not at all or only negligibly annoyed, a rating of 3 or 4 indicates that they are slightly annoyed, between 5 and 7 that they are annoyed and between 8 and 10 that they were highly annoyed.

Analysis

Analyzes were performed using IBM SPSS Statistics version 25.0 with a significance level of 5%.

First, descriptive analyses were conducted on the noise levels recorded in order to establish the annual average and the variation in levels for the different stations in 2018 and 2019, according to $L_{Aeq-24h}$, L_{Day}, $L_{Evening}$, L_{Night} and L_{10}. ANOVAs were computed to compare noise indicators between both surveys (2018 and 2019).

Then, a descriptive analysis of the data was performed by individually treating the variables included in the questionnaire as a dependent variable and using the group (target or control) as an independent variable. Two statistical tests were used to identify significant differences between groups according to the nature of the dependent variables (chi-square tests (χ^2) for categorical variables and ANOVA tests for continuous variables). A similar approach was used to compare the first and second surveys in order to examine the stability of the responses in the target and control groups. Where applicable, interactions between group and survey effects were identified and described.

RESULTS

Noise levels

Annual noise level for the different indicators are presented in Figure 3. Levels at night (L_{Night}) were the lowest, with a mean of 57.5 dBA ± 3.1 dBA in the first survey (2018), while the highest annual level was obtained for L_{Day} in the second survey (2019), with an average of 65.4 dBA ± 2.5 dBA. For each noise indicator, ANOVAs showed no significant difference between levels obtained in both surveys (L_{Aeq24h}, p = .161; L_{Day}, p = .146; $L_{Evening}$, p = .765; L_{Night}, p = .783; L10, p = .128).

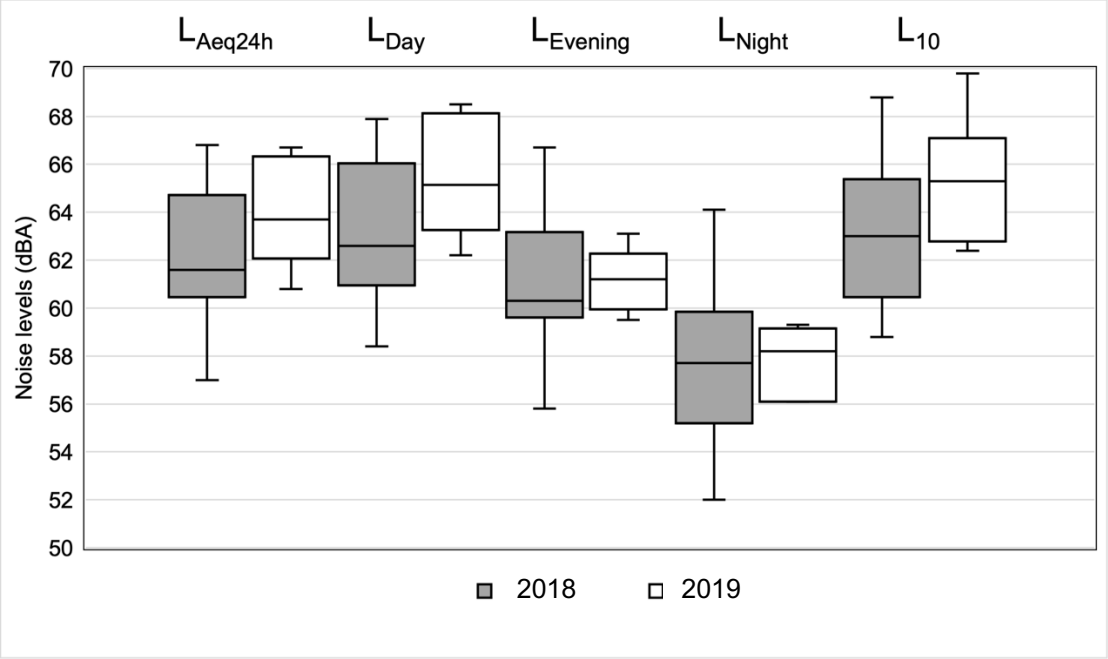

Figure 3: Box plots of yearly mean L_{Aeq24h}, L_{Day}, $L_{Evening}$, L_{Night} and L_{10} (in 2018 and 2019). The boxes represent the 25th-75th percentiles, central lines represent the median and bar stretch represent the standard deviation.

Sociodemographic variables

Most sociodemographic variables did not show difference between groups. In the first year, participants in the target group had a significantly lower family income (p < .001) and reported being less often owners of their dwelling (p < .001). In the second year, participants in the target

group reported a significantly lower family income (p = .011) and to spend more time at their residence (p = .035), and more participants reported a revenue related to the Turcot construction (p = .002). Most of these contextual variables are compatible with the demography of the studied region. For instance, a previous study analyzing family income and noise exposure on the island of Montreal illustrated that the areas closer to the Turcot complex (target group) were generally poorer neighbourhoods, while the areas further from the Turcot complex (control group) were generally richer neighbourhoods [12]. As for the differences in housing between groups, the 2016 Canadian census revealed that 12.4% of residences in some sections of the control zone were single-detached houses while this proportion dropped to 1.2% in sections of the target zone [13].

For the majority of socio-demographic, psychosocial and contextual variables, the absent participants in the second survey were similar to those present. However, significant differences were observed for age, residence status, work schedule, state of health, importance given to the sound environment and the intention to move in the next 12 months. Table 1 presents the significant differences between the participants present and absent at the time of the second perception survey in 2019 (target and control groups combined).

Table 1: Comparison of participants present and absent in survey 2 (significant differences only)

Variables	**Present (n=855)**	**Absent (n=554)**	**P-value**
Age	60.7 ± 14.1	58.5 ± 17.1	p = .012
Health	Excellent: 21% Very good: 31%	Excellent: 25% Very good: 24%	p = .032
Work timetable	Day work: 77%	Day work: 72%	p = .024
Residence status	Owner: 53%	Owner: 46%	p = .016
Importance given to the sound environment	2.1 ± 1.1	2.3 ± 1.1	p = .033
Planning to move within the next 12 months	Yes: 9%	Yes: 16%	p < .001

Perception survey

Construction noise annoyance

When the Turcot project construction noise annoyance score was analyzed as a continuous variable (0-10), no interaction was observed between the group and survey variables (p = .576). Of these two variables, only the group variable showed a significant difference (group, p < .001; survey, p = .675). The target group showed significantly more respondents annoyed or highly annoyed by construction noise from the Turcot project. Figure 4 illustrates the noise annoyance related to Turcot's construction work. For the first survey, 28% of the target group and 11% of the control group reported being highly annoyed. In the second survey, these proportions were 25% and 12% for the target and control groups respectively.

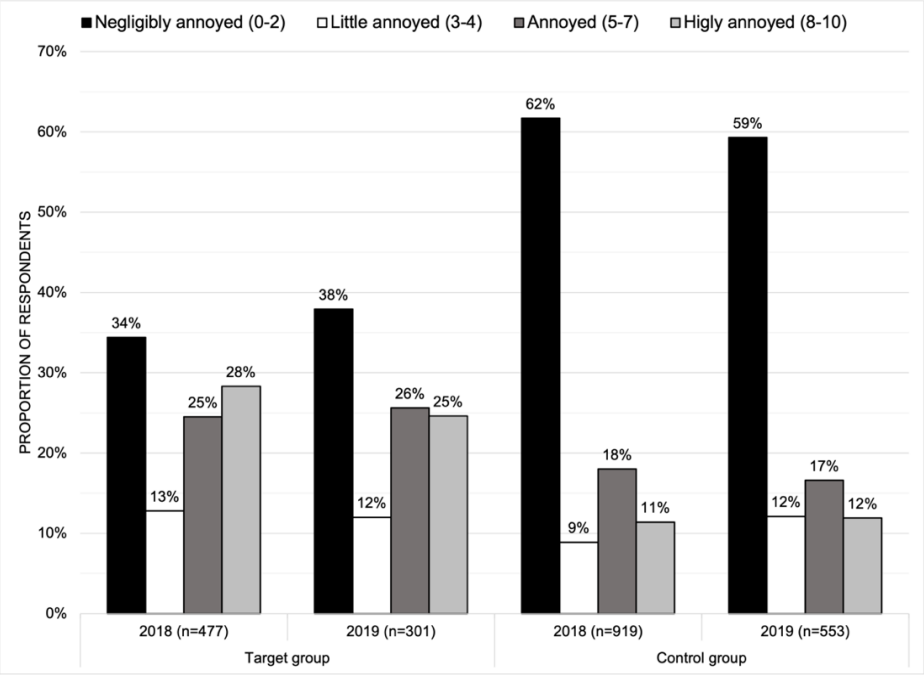

Figure 4: Levels of annoyance by noise generated from Turcot's construction activities in both groups and for each repetition of the survey (2018 and 2019).

When the Turcot construction noise annoyance score by period was analyzed as a continuous variable, no interaction was observed between the group and survey variables ($p = .491$). However, these two variables showed a significant difference (group, $p < .001$; survey, $p = .001$). Thus, Turcot's construction noise annoyance level per period was significantly higher in the target group. However, the annoyance increased similarly for the two groups between survey 1 and 2. Both groups showed a slight increase in the proportion of respondents highly annoyed for each time period between the first and the second survey (between 1% and 2.6% of increase, with the night period showing the larger increase in proportion for both groups). Figure 5 displays the proportion of highly annoyed participants in both groups by construction noise (day, evening, night) for both surveys.

Participants were also questioned on construction noise annoyance regarding daily activities (e.g., concentration, relaxation, indoor conversations and outdoor activities). When analyzed as a continuous variable, no interaction was observed between the group and survey variables ($p = .340$). Only the group variable showed a significant difference (group, $p < .001$; survey, $p = .852$). The target group showed a significantly higher level of annoyance than the control group, but this level was similar across surveys.

Finally, SCI scores were analyzed. A lower score indicated more difficulty sleeping. The scores were 5.13 ± 2.69 (mean ± standard deviation) for the target group and 5.68 ± 2.45 in the control group during the first perception survey ($p < .001$). During the second perception survey, the SCI scores were 5.27 ± 1.82 for the target group and 5.62 ± 1.75 in the control group ($p = .073$). When asked whether the source of the sleep disturbance was related to the construction work of the Turcot project, no interaction was observed between the group and survey variables ($p = .377$). However, the two variables showed a significant difference (group, $p < .001$; survey, $p = .001$). The sound source associated with sleep disturbance was significantly more related to Turcot's work for the target group than for the control group. More respondents in both groups indicated this sound source between surveys 1 and 2.

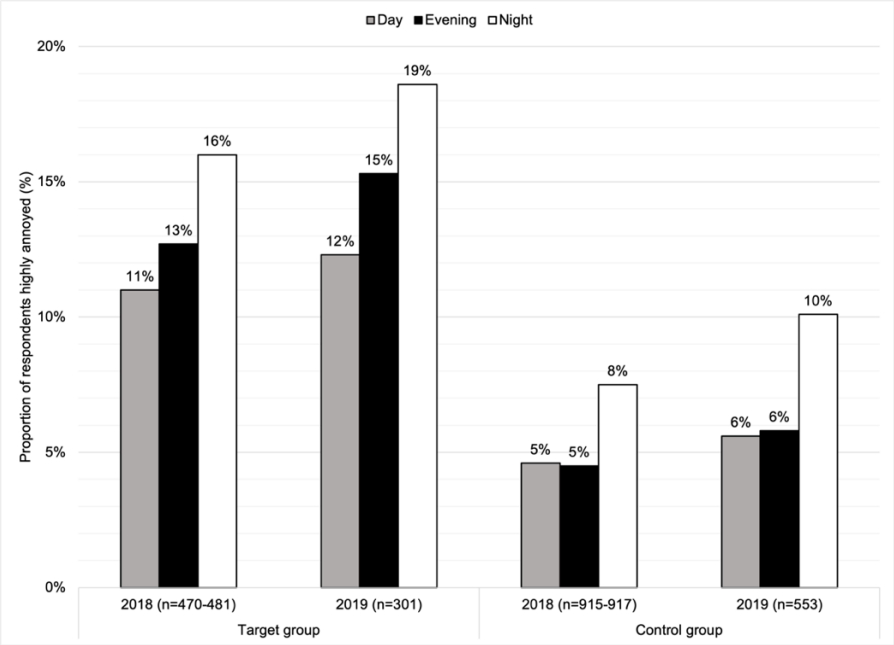

Figure 5: Proportion of highly annoyed respondents by noise generated from Turcot's construction activities (day, evening, night) in both groups and for each repetition of the survey (2018 and 2019).

Other sources of annoyance

When the environmental noise annoyance score (excluding traffic noise) was analyzed as a continuous variable, no interaction was observed between the group and survey variables ($p = .403$). Only the survey variable showed a significant difference (group, $p = .817$; survey, $p = .012$). Thus, for both groups, the overall annoyance score for the different sources of environmental noise decreased between surveys.

That being said, an interaction was observed between the survey and group variables ($p = .049$) concerning the continuous annoyance score to traffic noise. This annoyance variable seemed to decrease more rapidly in the target group between surveys (-8%) than in the control group (-4%). Figure 6 illustrates the annoyance related to traffic noise. For the first survey, 29% of the target group and 21% of the control group reported being highly annoyed. In the second survey, these proportions were 21% and 17% for the target and control groups respectively.

Participants were also questioned regarding annoyance to other aspects of construction work (e.g., dust, vibrations, odors). When analyzed as a continuous variable, no interaction was observed between the group and survey variables ($p = .089$). Of these two variables, only the group variable showed a significant difference (group, $p < .001$; survey, $p = .671$). The overall annoyance score for other aspects of Turcot's activities was significantly higher in the target group but remains similar across surveys.

Furthermore, the continuous annoyance score due to modifications to road traffic showed a significant survey difference (group, $p = .051$; survey, $p < .001$). No interaction was observed between the two variables ($p = .423$). The level of annoyance for traffic changes was therefore not significantly different between the groups (at the limit of significance), and this level decreased for the two groups between the surveys. Figure 7 shows the annoyance related to traffic modification. For the first survey, 55% of the target group and 48% of the control group reported being highly annoyed. In the second survey, these proportions were 49% and 43% for the target and control groups respectively.

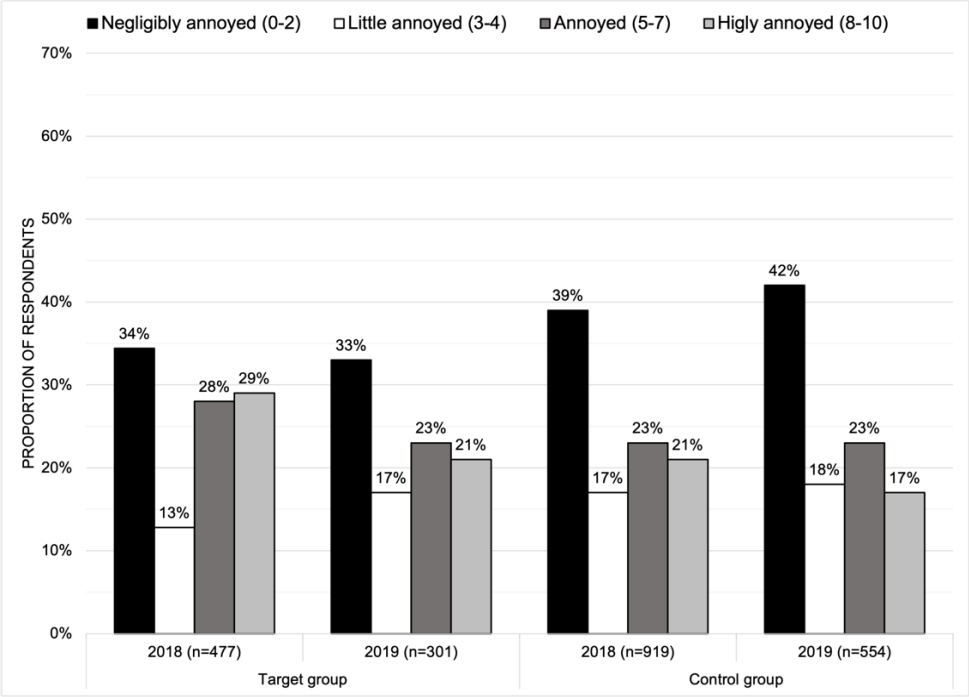

Figure 6: Levels of annoyance by traffic noise in both groups and for each repetition of the survey (2018 and 2019)

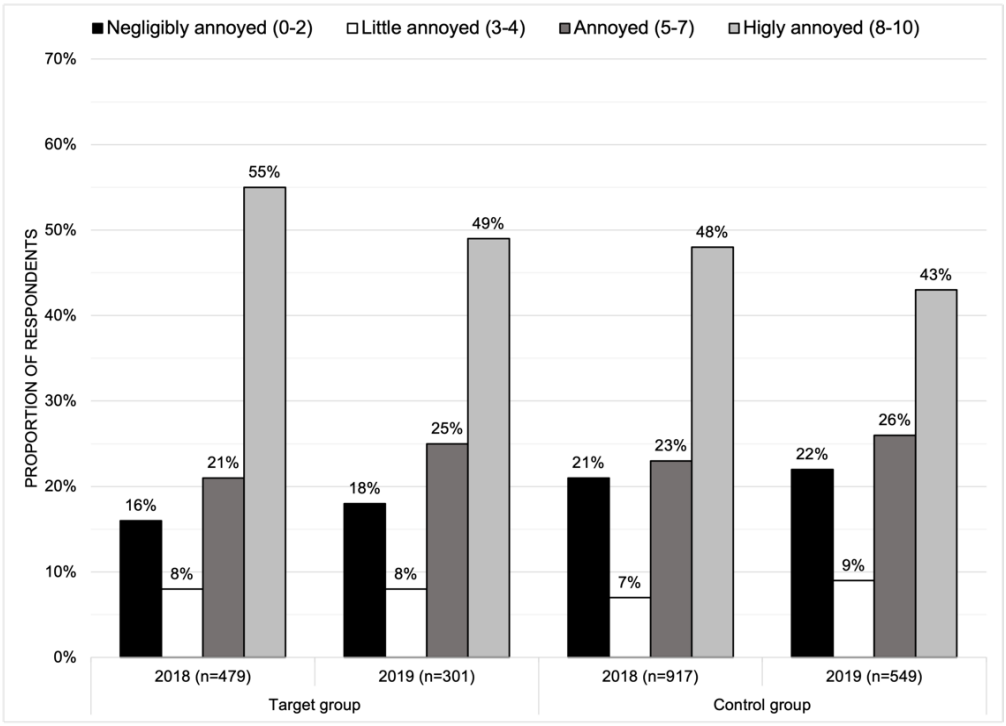

Figure 7: Levels of annoyance by traffic modifications in both groups and for each repetition of the survey (2018 and 2019)

DISCUSSION

Participants

In the first survey, most sociodemographic did not show any difference between group, except for family income and residence status. In the second repetition of the survey, family income showed similar differences between groups as the first year. The difference in residence status between groups was no longer significant (although just barely with $p = .075$). It could be hypothesized that residents who do not own their dwelling tend to be more mobile, and therefore could have been lost easier in the second year of the study.

Data from the group of participants who did not participate again in the second survey were analyzed to better understand the changes in annoyance over the time period of the study. The group of participants who took part in survey 2 is on average older, is made up of more owners, has more a daytime work schedule, perceives itself in better health, gives less importance to the noise environment and plans to stay in the neighborhood. In contrast, the group that did not participate again in the survey is on average younger, made up of more tenants, has a more atypical work schedule, considers itself in poorer health, gives more importance to the noise environment and planned to move.

Annoyance

Regarding traffic noise annoyance, annoyance levels in both groups were higher than previous reports. For instance, two studies conducted in the same province (i.e., the province of Quebec), found a prevalence of 4.1% [4] and 4.2% [14]. Methodological difference might explain part of the difference in the proportion of annoyance across studies. While we selected participants residing less than 300 m from the road project (target group) and between 300 m and 1,000 m (control group), most of the studies previously reported did not select participants specifically close to a large highway. When comparing both surveys, traffic noise annoyance was the only variable which displayed an interaction between groups and surveys, with a reduced annoyance level in both groups, but more important in the target group.

For residents living up to 300 m from the large construction site of the Turcot project, construction noise was found to be the most annoying environmental noise sources (25 to 28% of highly annoyed respondents). This proportion was higher than reported prevalence of annoyance to construction noise in another study conducted in the same province (i.e., 4.6% in the province of Quebec, Canada), but this study did not investigate annoyance for residents living specifically close to a large road infrastructure undergoing major rehabilitation work [4]. The proportion of respondents highly annoyed by construction noise in the control group was significantly smaller (11 to 12%), which was to be expected.

Taken together, our results showed that on all variables related to construction noise annoyance (e.g., overall, by period, daily activities, sleep), the target group displayed significantly higher levels of annoyance than control group. For two of these variables (e.g., overall and daily activities), annoyances levels were similar between both surveys (2018 and 2019). The questions regarding annoyance levels by time of day (e.g., day, evening and night) exhibited an increased in annoyance levels in the second survey for both groups. The data seems to suggest that this increase might by related to the larger proportion of participants highly annoyed by construction noise in the nighttime period. This hypothesis is supported by the sleep annoyance variable, which also displays an increased level of annoyance between surveys. A question measuring annoyance for different periods of the day therefore seems more appropriate to

detect variations in construction noise annoyance in a longitudinal socio-acoustic survey than a general annoyance question.

It is interesting to see that all annual noise indicators (e.g., L_{Aeq24h}, L_{Day}, $L_{Evening}$, L_{Night}, L_{10}) remained stable between both surveys. Therefore, while annoyance levels for the nighttime period and sleep annoyance increased, this was not related to an increased in noise levels. This is supported by published data from our research team that showed that noise levels only explained a marginal proportion of variance in annoyance levels (less than 1%) [5].

Two variables not related to construction noise (e.g., annoyance to other environmental noise sources and annoyance to traffic modifications) showed similar levels of annoyance for both groups. For these, annoyance levels were significantly reduced in the second survey. On the other hand, annoyance to other constructions aspects (e.g., dust, odours, vibrations) remained similar in both surveys. We might hypothesis that as construction work is progressively completed, the rerouting of local circulation diminishes, which might explain the reduction in annoyance regarding this aspect. Although, since work is still being conducted, the other construction aspects are still perceived as a nuisance for local residents.

Limits

The main strength of this study was the sheer size of the sample, which consisted of 1409 participants in the first survey (2018) and 855 participants in the second survey (2019). This size allowed a robust statistical power to identify small effects that may go unnoticed in studies using smaller samples.

One limitation of the study concerned the temporal distribution of the various construction sites throughout the territory covered by the Turcot's construction site. The scale of the Turcot project (i.e., ten kilometers) and the diversity of the work that is carried out at a specific moment in time from one area to another of the site inevitably introduced "noise" in data collected. Thus, at a specific time during the administration of the survey, some participants near the road project were not exposed to work while respondents located in another area, could at the same time be exposed to construction work. Also, although these first data give us insight in longitudinal changes, it is possible that participant less annoyed are the ones that were not interested to participate on this study, causing an "artificial" change in the prevalence of highly annoyed respondents on certain variables.

CONCLUSION

As the different noise indicators (e.g., $L_{Aeq-24h}$, L_{10}, L_{Night}) remained relatively stable, participants also reported stable annoyance levels over a 2-year period. However, when questioned according to different periods of the day, construction noise annoyance increased between surveys. To avoid missing any variation in annoyance, time periods should be taken into account in socio-acoustic surveys regarding construction noise especially if work is being completed during evenings and nights. The increase in nighttime and sleep annoyance was not supported by an elevation in L_{Night} noise. These first longitudinal results (year 1 and 2) support previously published work from our research team [5]. We found that socio-demographic, psychosocial and contextual factors, such as the perceived effect of construction on the value of the residence and the fact that the bedroom is usually exposed to noise, accounted for a larger proportion of variance in annoyance for noise at different time periods.

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