THE ASSOCIATION OF ACOUSTIC AND NON-ACOUSTIC FACTORS WITH SEVERE AIRCRAFT NOISE ANNOYANCE – RESULTS OF THE SURVEY OF NOISE IMPACTS ON CANADIAN COMMUNITIES

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Résumé

De nombreux Canadiens sont affectés à divers degrés par des bruits dérangeants. Ceux qui vivent près des aéroports et des trajectoires de vol, sont exposés aux bruits des aéronefs qui peuvent causer de graves perturbations. Ses perturbations, sont l'effet le plus commun lors de l'exposition aux bruits aéronefs et elle constitue un paramètre clé dans les règlements et les directives provenant. Avec cela étant dit, il y a aussi des perturbations occasionnelles par des avions qui n'affecte pas les humains et cela est parce que leur niveau sonore n'est pas assez élevé pour devenir une nuisance. Une compréhension approfondie de la nuisance sonore et de tous ses facteurs acoustiques et non-acoustiques qui peuvent y contribuer est essentielle à sa gestion. Le Survey of Noise Impacts on Canadian Communities 2021 (SONICC 2021) est un questionnaire distribué dans les régions où se trouve un aéroport international, tel que Pearson à Toronto, qui visent à identifier les facteurs sonores, acoustiques et non-acoustiques, qui leur perturbaient le plus. Bien que l'analyse présentée dans ce document note que la prévalence de l'exposition aux bruits augmente les dérangements, les niveaux sonores seuls n'étaient pas le meilleur indicateur de la probabilité qu'une personne soit perturbé. La prise en compte de facteurs situationnels, personnels et attitudinaux tels que la perception d'un changement de bruit, l'accoutumance, le sentiment d'injustice et la sensibilité au bruit a considérablement amélioré la capacité à prédire la gêne qui est plus sévère. Cet article présente les résultats de l'étude SONICC 2021 et suggère comment ces résultats peuvent contribuer à une approche plus globale de la prédiction et de l'atténuation de la gene.

Mots clefs: Bruit des aéronefs, gêne induite par le bruit, facteurs non-acoustiques, enquête sur la gêne, prédiction de la gene

Abstract

Many Canadians are affected to various extends by environmental noise. Those living near airports and flight paths are exposed to aircraft noise that can cause severe disturbance and annoyance amongst the population. Annoyance is the most common effect of aircraft noise exposure, and as such, is a key metric in regulations and guidelines. However, it is anecdotally understood that annoyance from aircraft noise cannot be attributed to a measured noise level alone and that there are other contributing factors. Thorough understanding of noise annoyance and all possible acoustic and non-acoustic contributors is critical to its management. The Survey of Noise Impacts on Canadian Communities 2021 (SONICC 2021) was a questionnaire distributed around Toronto Pearson International Airport, which sought to identify both acoustic and non-acoustic factors associated with severe noise annoyance. While the analysis in this paper noted that prevalence of severe annoyance increased with higher noise exposure, noise levels alone were not the best predictor of a respondent's likelihood of being highly annoyed. Consideration of situational, personal, and attitudinal factors such as perceived change in noise, habituation, feeling of unfairness, and noise sensitivity significantly improved the ability to predict severe annoyance. This paper shares the results of SONICC 2021 and suggests how these findings can inform a more holistic approach to annoyance prediction and mitigation.

Keywords: Aircraft noise, noise-induced annoyance, non-acoustic factors, annoyance survey, annoyance prediction

1 Introduction

Aircraft noise can impact many communities surrounding an airport, especially when the airport is near or within an urban environment, as is the case for Toronto Person International Airport. Prolonged exposure to high and even moderate levels of aircraft noise has been speculated to have numerous psychological and physiological effects. Cardiovascular disease, cognitive impairment, sleep disturbance and annoyance are considered the critical health outcomes of environmental noise exposure by the World Health Organization, although further research is necessary to support these findings (WHO) [1].

Annoyance is the most well-corroborated and common effect of environmental noise and is understood as a feeling of displeasure, disturbance, or irritation that is caused by an unwanted sound [2]. It is recognized as a health effect endpoint of long-term environmental noise exposure as well as a modifying factor contributing to other health effect endpoints such as hypertension. [3]

Aircraft noise annoyance is the principal metric used to gauge the impacts of aircraft noise on communities. It is also used as the basis for regulations and guidelines aimed at protecting people from the effects of excessive noise exposure [4, 5]. To help quantify the relationship between annoyance

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and noise exposure, dose-response functions have been developed and updated since the 1970's. These functions correlate cumulative noise exposure levels to the percentage of the population that is highly annoyed (%HA) by the exposure. The International Commission on Biological Effects of Noise considers %HA to be the main indicator of community annoyance [6].

Dose-response functions are used to inform both annoyance prediction and mitigation. While clearly a relationship exists between the level of noise and annoyance, much variance is seen in the data [7]. The variance in dose-response functions cannot be explained by acoustic factors alone. Studies have consistently identified the influence of non-acoustic factors on annoyance. Personal, situational, and attitudinal variables have been found to be contributors to annoyance. [8-11] A better understanding of the non-acoustic components will enhance annoyance prediction and better inform effective mitigation measures.

The Survey of Noise Impacts on Canadian Communities (SONICC) assessed a number of non-acoustic and acoustic variables and their association to severe annoyance. In this work, an annoyance prediction model with noise exposure as the sole predictor of severe annoyance is compared to an alternate model having both acoustic and non-acoustic variables as the predictors. Further, the results of SONICC 2021 are discussed in an effort to develop a more holistic understanding of the mindsets of HA and NON-HA respondents.

2 Method

2.1 Data collection

SONICC was distributed in the spring of 2021 to the communities around Toronto Pearson International Airport. 8,000 addresses were randomly selected in areas having various aircraft noise exposure levels, as identified by the modelled aircraft noise contours shown in Figure 1. An equal number of surveys were intended for distribution in five zones, although the zones with the highest noise exposure had few or no residential addresses. The surveys that were intended for these zones were equally distributed amongst the remaining zones. The distribution and response rates from each zone are outlined in Table 1. Respondents to the survey were given an option to reply by mail (using enclosed return envelope), online or via device using a QR code. From
the returned responses, those that did not provide an address to facilitate the study's noise calculations were eliminated from the analysis as it would not be possible to determine their noise contour range of exposure. The remaining 720 responses were further filtered to eliminate those that did not respond to the ISO noise annoyance questions. Altogether, 693 surveys were included in the analysis that was used in this paper.

Figure 1: SONICC survey distribution zones based on PPD NEF. contours.

2.2 Questionnaire

SONICC 2021 was comprised of three sections that examined various demographic, situational, personal, and attitudinal factors identified in the literature as possible contributors to severe annoyance. *Part A – Neighbourhood and Home Related Quality of Life* included questions about the respondent's self-reported exposure to aircraft noise, their assessment of how aircraft noise has changed over the past year, their expectations for how aircraft noise will change over the coming years, the length of residency in their current home, their ability to habituate to the noise, their expectations of noise exposure when first moving to the neighbourhood, and the approximate value of their home. *Part B – Demographics* contained questions about age, gender, education, and approximate household income. *Part C – Noise Source and Impacts* assessed the levels of long-term annoyance using two questions from ISO/TS 15666:2003(E) [12] given as follows:

Table 1. SONICC distribution zones, return rates, HA distribution

Zone	Zone description	# of surveys	% of total distribution	# of surveys returned	Rate of return	# of HA respondents	% HA
1	NEF 40+	0	0%	0	0%	0	0%
2	NEF 35-40	1	0%	0	0%	0	0%
3	NEF 30-35	1,202	15%	77 (RR 6.4%)	11%	20	26%
4	NEF 25-30	3,398	42%	332 (RR 9.8%)	46%	66	20%
5	15 km – NEF 25	3,399	42%	309 (RR 9.1%)	43%	17	6%

(5 – Point Annoyance Question)
Thinking about the last (12 months or so), when you are here at home, how much does noise from aircraft bother, disturb or annoy you?

_Not at all
_Slightly
_Moderately
_Very
_Extremely

(11- Point Annoyance Question)
Thinking about the last (12 months or so), what number from 0 to 10 best shows how much you are bothered, disturbed, or annoyed by aircraft noise? [12]

Respondents were also asked to identify, from a list of seven examples, the noise sources that affect them while at home. The noise sources included neighbourhood (i.e., lawn mowers), entertainment (i.e., music, fireworks), traffic (i.e., automobile), railroad, construction, aircraft, and product (i.e., AC, dishwasher, fridge). Respondents were asked to select all that apply. A multi-noise score (1-7) was assigned to each respondent based on the number of noise sources selected. In addition, other personal and attitudinal factors were examined such as misfeasance with authorities; a score given based on an average of responses to three questions about the belief that there is a lack of communication, action, and accountability by authorities. A feeling of unfairness score was calculated based on the responses to two questions relating to the belief that there is a lack of compensation for tolerating the noise and the belief that there is an unfair distribution of noise. An attitude towards airport authorities score was an average calculated based on the responses to the following questions:

My local airport (1 - Strongly disagree to 5 - Strongly agree):

- Is an organization I trust
- Is well managed
- Is profit driven
- Is efficient
- Is transparent/open
- Is engaged in the community
- Is environmentally responsible
- Is socially responsible
- Handles emergency situations well
- Manages noise well

The answers to these questions were normalized to a 1 - 5 scale, 1 being a negative attitude towards authorities and 5 being a positive attitude towards authorities, prior to averaging. Thus, a question that is 'positively' worded such as 'is an organization I trust', the 1-5 scale remains as the respondent answered, while a question that is negatively worded such as 'is profit driven', the 1-5 scale is reversed from the respondent's answer (i.e., 1 becomes a 5, 2 becomes a 4 and 3 remains the same). Any unanswered questions were omitted from the calculation of the average score.

A respondent's attitude towards the noise and the noise source was also given a score based on the average response to the following questions (1 - Strongly agree to 5 - Strongly disagree):

- Air travel is fun and useful
- Aircraft noise affects my physical health
- Aircraft noise affects my mental health
- Having an airport in the area is good for the economy (jobs, tourism etc.)
- Air travel causes air pollution
- Night flights are an essential part of airport operations
- Air travel is dangerous
- Cargo flights are essential for timely delivery of goods
- Aircraft noise makes my home less valuable
- It is convenient to have an airport in the area
- Air travel contributed to the spread of COVID 19

The answers to these questions were normalized in the same manner described above, prior to averaging. A low score relates to a negative attitude towards the noise and source and a high score relates to a positive attitude. A further question assessed the respondent's noise sensitivity (1 – not at all sensitive to 5 – extremely sensitive to noise). Lastly, the respondent's coping capacity was determined based on the dichotomous answer to the question 'When I am bothered by noise, I feel helpless / cannot escape the noise '(1 – True/lack of coping capacity, 2 – False/presence of coping capacity). Additional questions were included in SONICC that were not used as variables in the prediction models, but rather to further the understanding of the impacts and perceptions of aircraft noise in affected communities.

2.3 Noise exposure modelling

The noise exposure at each response location was modelled using AEDT 3C. The noise exposure was modelled using the DNL (day-night level) metric, which is an averaged noise level over a 24-hour period with a 10 dBA penalty added for nighttime noise (23:00-7:00). Although Canada uses the Noise Exposure Forecast (NEF) metric for predictions of aircraft noise impacts, the DNL metric is more comparable to the international literature. The aircraft noise exposure was modelled for the 95th percentile day or peak planning day (PPD) traffic volumes, according to the methodology mandated by Transport Canada, for the 12-month period prior to the distribution of the survey [5].

2.4 Statistical analysis

Two statistical analyses were performed on the data, an independent t-test and a logistic regression. To begin, an independent t-test was performed for each variable identified in the survey in order to assess if the means of the highly annoyed (HA, annoyance score above 72) and non-highly annoyed (NON-HA, annoyance score below 72) groups of respondents are statistically different. By performing the independent t-test first, it was possible to identify all the variables of interest which demonstrate clear differences of sentiments between HA and NON-HA respondents. The results of this analysis are given in Tables 2-5.

In the next part of the statistical analysis, two logistic regression models were tested. Model 1 had the level of noise exposure as the only variable to predict one's likelihood of

being HA. Model 2, in addition to noise exposure, included several non-acoustic predictor variables. The variables identified as statistically significant from the independent t-test were first evaluated for collinearity using collinearity statistics from a linear regression model. From the original eleven variables, two were removed due to collinearity: self-reported noise exposure (possibly collinear with modelled noise exposure level) and misfeasance with authorities (possibly collinear with attitude towards airport authorities). The nine remaining variables were used as inputs in a binary logistic model. The results of the logistic regression are outlined in Table 6.

3 Results / Discussion

The overall response rate for SONICC 2021 was 9.31%. Some responses were excluded from the analysis due to incompleteness of critical questions, leaving 693 valid responses. From these, 21% reported being highly annoyed by aircraft noise over the last 12 months; the remaining 79% were NON-HA.

3.1 Acoustic and non-acoustic variables - Results of independent sample t-test

Table 2 outlines the distribution of HA and NON-HA respondents by noise exposure interval. The highest number of respondents are from areas which are exposed to noise above DNL 55 dBA. This is not unexpected because communities affected by higher levels of noise are more likely to be engaged in the topic of aircraft noise, and therefore more likely to participate in the survey. More than half (54%) of the HA respondents come from areas exposed to DNL 60 dBA or more, while only 25% of NON-HA come from those exposure levels. 88% of HA are exposed to noise above DNL 55 dBA. The data in Table 2 shows that the mean noise exposure for HA and NON-HA is statistically different, thus noise level is a potential acoustic factor that can help in the prediction of severe annoyance.

Table 2: Noise exposure by annoyance - SONICC survey.

	HA		Non-HA		p-value	Total
	n	%	n	%		n
Aircraft Noise (DNL)					**<0.001**	
<35 dBA	1	1%	82	14%	--	83
35-39 dBA	3	2%	75	13%	--	78
40-44 dBA	3	2%	36	6%	--	39
45-49 dBA	2	2%	52	9%	--	54
50-54 dBA	6	5%	78	14%	--	84
55-59 dBA	41	34%	104	18%	--	145
>60dBA	66	54%	144	25%	--	210

*n is the number of surveys, p-value is the significance level, values below 0.001 are statistically significant.

Table 3 summarizes the results of the independent t-test for Section A of SONICC. Six variables were tested for statistically significant differences of means between the HA and NON-HA respondents. The results demonstrate whether HA respondents are more likely to respond differently to a question than NON-HA respondents. Questions that have statistically different responses between the two groups are identified as variables that can possibly contribute to the prediction of noise annoyance and are selected as inputs for the logistic regression performed in the second stage of the analysis.

Self-reported noise exposure was found to be a statistically significant variable. 63% of all respondents reported being exposed to aircraft noise continuously or always. This is not unexpected due to the targeted distribution of the survey to areas that are known to be affected by aircraft noise. This percentage increases to 98% of HA respondents reporting being exposed to aircraft noise continuously or always. Some consideration was given to a possible response bias, where HA respondents could be reporting an amplified level of exposure. This was rebutted by a mapping of the respondent locations who answered 'continuously' or 'always' to the self-reported noise exposure question. This mapping confirmed that most of 'continuously' or 'always' respondents were indeed located in areas that were likely subjected to significant noise exposure on a regular basis. Thus, self-reported noise exposure is a variable that can be used in an annoyance prediction model, particularly when there is a lack of access to noise data (modelled or measured).

Perceived change in noise was also found to be statistically significant. 25% of HA respondents reported that there was a significant increase in noise in the past 12 months compared to only 2% of NON-HA. This result was unexpected given that the 'last 12 months' (approximately May 2020 to May 2021) that were being assessed experienced significant reductions of aircraft traffic due to COVID 19 travel restrictions which were first implemented in March 2020. On closer examination, reduced traffic volumes at Toronto Pearson allowed for some condensed flight paths that concentrated traffic over a narrower corridor which may have created a perception of increased volume for some people, but conversely would also reduce the exposure for others. This finding highlights the possibility of increased prevalence of severe annoyance with narrowing flight paths such as Required Navigation Performance (RNP) routes, which are proposed to be implemented for all airports in the European Union in the coming years [13].

Additionally, 41% of the HA respondents acknowledged that noise has either somewhat or significantly decreased over the last 12 months, yet they remain HA. This is a disconcerting finding for authorities who invest significant efforts to reduce cumulative exposure by 1-2 dBA in hopes of reducing community annoyance. Perceived change in noise can potentially be an acoustic (if confirmed by objective assessment) or non-acoustic factor that can contribute to annoyance prediction.

HA respondents' expectations for future noise were also found to be statistically different compared to those of NON-HA. 80% of HA respondents expected that noise will somewhat or significantly increase over the coming years, while only 58% of NON-HA shared this sentiment. Thus, expectation for future noise is identified as a non-acoustic factor that

Table 3: Results of SONICC 2021 Section A-Neighbourhood and Home Related Quality of Life

		HA		NON-HA		p-value	TOTAL
		n	%	n	%		n
Self-reported noise exposure						**<0.001**	
blank	No answer	0	0%	9	1%	--	9
1	Continuously	55	45%	61	11%	--	116
2	Always	65	53%	254	45%	--	319
3	Sometimes	2	2%	205	36%	--	207
4	Never	0	0%	42	7%	--	42
Perceived change in noise over the past 12 mo.						**<0.001**	
blank	No answer	3	2%	20	4%	--	23
blank	No aircraft noise exposure	0	0%	28	5%	--	28
1	Significantly increased	31	25%	10	2%	--	41
2	Somewhat increased	11	9%	26	5%	--	37
3	Stayed the same	23	19%	102	18%	--	125
4	Somewhat decreased	33	27%	153	27%	--	186
5	Significantly decreased	17	14%	203	36%	--	220
blank	Don't know	4	3%	29	5%	--	33
Future expectations for noise						**<0.001**	
blank	No answer	4	3%	14	2%	--	18
1	Significantly increase	78	64%	191	33%	--	269
2	Somewhat increase	20	16%	145	25%	--	165
3	Stay the same	4	3%	100	18%	--	104
4	Somewhat decrease	1	1%	22	4%	--	23
5	Significantly decrease	6	5%	8	1%	--	14
blank	Don't know	9	7%	91	16%	--	100
Past expectations for how affected one expected to be by aircraft noise upon moving to their home						0.012	
blank	No answer	2	2%	10	2%	--	12
1	Unaffected / not affected	30	25%	220	39%	--	250
2	Less affected	31	25%	78	14%	--	109
3	Somewhat affected	46	38%	247	43%	--	293
4	Greatly affected	13	11%	16	3%	--	29
Length of residency						0.999	
blank	No answer	1	1%	6	1%	--	7
1	Less than 1 year	0	0%	6	1%	--	6
2	1-2 years	2	2%	9	2%	--	11
3	3-4 years	8	7%	20	4%	--	28
4	5 years or longer	111	91%	530	93%	--	641
Habituation to noise						**<0.001**	
blank	No answer	5	4%	16	3%	--	21
0	No	89	73%	178	31%	--	267
1	Yes	25	20%	212	37%	--	237
blank	Not bothered by noise	3	2%	165	29%	--	168

can contribute to annoyance prediction.

A question was included in the survey to assess a respondent's expectations for aircraft noise exposure prior to moving into their current home. This question did not show a statistically significant difference in responses between HA and NON-HA, mainly because the majority of both groups did not expect to be as affected by aircraft noise prior to moving to their home. This exposes a problem with access to valid information / guidelines. Health Canada in their most recent guidance on aircraft noise, recommend that an individual

planning to move to a neighbourhood near an airport, should consult the noise contour map for the area and follow guidelines outlined in a Transport Canada document entitled TP 1247E Part IV Aircraft Noise [5, 14]. This guideline offers outdated and misleadingly concise predictions as to the expected community reaction to different aircraft noise levels. A better understanding of acoustic and non-acoustic factors affecting severe annoyance would allow for more informed guidance for those contemplating a move to an aircraft noise affected area. This in turn could help mitigate the levels of severe annoyance in communities surrounding the airport.

The 'length of residency' was not found to be a statistically significant variable as most respondents reported having lived in their current home for 5 years or more. On the other hand, habituation to noise was found to be statistically significant. 73% of HA respondents reported not being able to get used to the noise, while only 31% of NON-HA reported the same, making it a possible non-acoustic contributor to annoyance.

Table 4 shows the results of the demographic variables examined in Section B of SONICC. None of the demographic factors including home value, age, gender, education, and household income showed a statistically significant difference between HA and NON-HA respondents. This is important because it is often hypothesized that demographic factors have an impact on annoyance, despite this being consistently disproven [9, 15].

Table 5 evaluates numerous situational, attitudinal, and personal factors from Section C of SONICC. The first variable is a multi-noise source score. Respondents were asked which noise sources impacted them while at home. The hypothesis being tested was that HA respondents would report being affected by more noise sources than NON-HA. This was not the case and there was no statistically significant difference between the two groups.

All attitudinal factors, misfeasance with authorities, feeling of unfairness, attitude towards airport authorities, and attitudes towards the noise and noise source, were found to be statistically significant. The HA group had a significantly higher misfeasance with authorities and feeling of unfairness average scores in comparison to NON-HA respondents. HA also had significantly more negative attitudes towards authorities and the noise/source.

Personal factors like sensitivity to noise and coping capacity were also found to be statistically significant. 54% of HA reported being very or extremely sensitive to noise, while only 19% of NON-HA reported the same. 75% of HA respondents lacked coping capacity and reported feeling helpless and unable to escape the noise in comparison to 26% of NON-HA. Situational, attitudinal, and personal factors are all non-acoustic variables, yet they formed the bulk of inputs in the logistic regression model for the prediction of severe annoyance, demonstrating the significant implications of excluding non-acoustic factors from the prediction and mitigation of annoyance.

As stated earlier, the independent t-test was performed first and the logistic regression second. This was because a logistic regression significantly lowered the size of the study sample. Due to the nature of the survey (mailed, not in-person interview) many respondents did not answer every question. Only those that answered the survey in its entirety were analyzed in the logistic regression, effectively reducing the sample size from 693 to 285. A logistic regression can sometimes render critical variables as statistically insignificant due to a small sample size, and inversely trivial variables can be identified as statistically significant in large sample sizes [16].

3.2 Noise annoyance prediction model – Results of logistic regression

Based on the results of the independent t-test, nine variables (1 acoustic and 8 non-acoustic) were tested in two binary logistic models. The first model had only noise exposure level (DNL) as a predictor variable. This model, although statistically significant, was not a good predictor of severe annoyance. It did not predict a single HA respondent. The second model significantly improved prediction by predicting nearly 68% of the HA cases. This model identified five variables that can predict better than chance someone's likelihood of being HA. Aircraft noise level (DNL), perceived change in noise, habituation to noise, feeling of unfairness, and self-reported noise sensitivity were found to be statistically significant in this model. Amongst these variables, noise sensitivity and feeling of unfairness, both non-acoustic variables, had the highest association to severe annoyance. The OR values of each variable in both models are listed in Table 6 and can be seen in Figure 2.

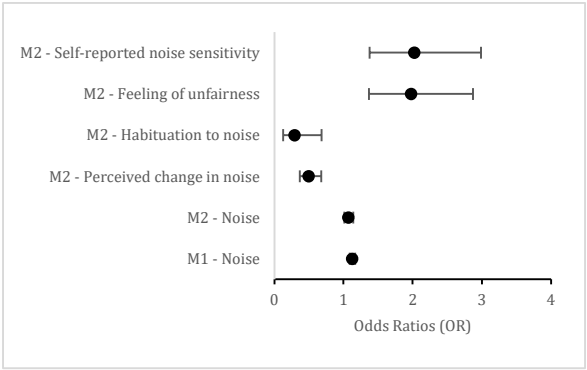

Figure 2: Model 1 and Model 2 variables and odd ratios

The analysis in Table 6 highlights the role of non-acoustic factors in annoyance predication. The only two acoustic variables that were found to be statistically significant predictors of annoyance; the modelled aircraft noise level and the perceived change in noise (self-reported and not verified), have the lowest odds ratio (OR) from the statistically significant variables, considering that an OR of 1 means no association between exposure and outcome. Even when the noise level is plugged into the model at intervals of 4 dBA, the OR ratio only increases to 1.48. Conversely, non-acoustic factors such as habituation to noise, feeling of unfairness, and noise sensitivity, were all found to be statistically significant variables with higher association to the outcome of severe annoyance than the acoustic factors tested. Thus, non-acoustic variables are as, if not more important in the study, prediction, and perhaps even mitigation of noise annoyance than acoustic ones.

Table 4: Results of Section B Demographics of SONICC survey.

		HA		NON-HA		p-value	TOTAL
		n	%	n	%		n
Self-reported home value						0.084	
blank	No answer	26	21%	101	18%	--	127
1	Under 200 000	2	2%	5	1%	--	7
2	200 001 - 4000 000	2	2%	11	2%	--	13
3	400 001 - 600 000	3	2%	33	6%	--	36
4	600 001 - 800 000	11	9%	76	13%	--	87
5	800 001 - 1 M	27	22%	129	23%	--	156
6	1M +	42	34%	151	26%	--	193
blank	Don't know	9	7%	65	11%	--	74
Age						0.468	
blank	No answer	8	7%	33	6%	--	41
1	Under 18	0	0%	1	0%	--	1
2	18-19	0	0%	1	0%	--	1
3	20-24	0	0%	3	1%	--	3
4	25-34	1	1%	11	2%	--	12
5	35-44	13	11%	44	8%	--	57
6	45-54	15	12%	74	13%	--	89
7	55-64	35	29%	134	23%	--	169
8	65-74	30	25%	144	25%	--	174
9	75+	20	16%	126	22%	--	146
Gender						0.898	
blank	No answer	26	21%	77	13%	--	103
1	Female	44	36%	229	40%	--	273
2	Male	52	43%	263	46%	--	315
blank	Other	0	0%	2	0%	--	2
Education						0.384	
blank	No answer	22	18%	52	9%	--	74
1	Master/Doctorate	20	16%	74	13%	--	94
2	Post-secondary	56	46%	314	55%	--	370
3	High school	21	17%	118	21%	--	139
4	Elementary	3	2%	13	2%	--	16
Household income						0.551	
blank	No answer	56	46%	186	33%	--	242
1	Under 20,000	2	2%	15	3%	--	17
2	20,000-46,605	11	9%	67	12%	--	78
3	46,606-93,208	20	16%	139	24%	--	159
4	93,209-144,489	20	16%	90	16%	--	110
5	144,490-205,842	9	7%	48	8%	--	57
6	205,843 +	4	3%	26	5%	--	30

3.3 Additional survey questions and findings

Some additional questions were included in SONICC that provided insight into the nature of the noise disturbance, its impacts, and the affected populations. When asked about the level of disturbance / annoyance from various noise sources including neighbourhood activities, entertainment, traffic, railroad, construction, aircraft, and product, both HA and NON-HA ranked aircraft noise as the most annoying, followed by traffic and neighbourhood (HA)/entertainment (NON-HA). HA respondents' average level of annoyance

Table 5: Results of Section C Noise Source and Impacts of SONICC survey.

		HA		NON-HA		p-value	TOTAL
		n	%	n	%		n
Multi-noise source score (neighbourhood, entertainment, traffic, railroad, construction, aircraft, product)						0.240	
blank	No answer	1	1%	20	4%	--	21
1	Affected by 1 source	23	19%	143	25%	--	166
2		45	37%	141	25%	--	186
3		28	23%	110	19%	--	138
4		14	11%	81	14%	--	95
5		9	7%	42	7%	--	51
6		2	2%	17	3%	--	19
7	Affected by all 7 sources	0	0%	17	3%		17
Misfeasance with authorities		Avg Score		Avg Score		**<0.001**	Avg Score
1	No misfeasance	4.06		2.52		--	2.88
to						--	
5	High misfeasance					--	
Feeling of unfairness		Avg Score		Avg Score		**<0.001**	Avg Score
1	No feeling of unfairness	4.39		2.66			3.08
to							
5	High feeling of unfairness						
Attitude towards airport authorities		Avg Score		Avg Score		**<0.001**	Avg Score
1	Negative attitude	2.18		3.05			2.9
to							
5	Positive attitude						
Attitude towards noise and source		Avg Score		Avg Score		**<0.001**	Avg Score
1	Negative attitude	2.48		3.34			3.14
to							
5	Positive attitude						
Self-reported noise sensitivity						**<0.001**	
blank	No answer	0	0%	3	1%		3
1	Not at all	1	1%	90	16%		91
2		11	9%	109	19%		120
3	Somewhat	47	39%	263	46%		310
4		28	23%	68	12%		96
5	Extremely	35	29%	38	7%		73
Coping capacity (feeling helpless)						**<0.001**	
blank	No answer	10	8%	85	15%		95
1	Lack of coping capacity	92	75%	148	26%		240
2	Presence of coping capacity	20	16%	278	49%		298
blank	Not bothered by noise	0	0%	60	11%		60

from each noise source mentioned above was higher than NON-HA, possibly pointing to an inherent noise sensitivity in HA respondents that was also supported by the responses to the self-reported noise sensitivity question.

To understand if there is a statistical difference between aircraft noise HA vs NON-HA respondents' sentiments towards other noise sources, respondents' annoyance ratings for all seven noise sources were tested with an independent sample t-test. Response differences were only statistically significant for traffic noise. Those highly annoyed by aircraft noise were more likely to also be severely annoyed by traffic noise compared to those that were non-highly annoyed by

Table 6 : Significance, Odds Ratios (OR) and 95 % Confidence Intervals (CI) for HA in relation to noise exposure (DNL) and non-acoustic factors. Note : Model is statistically significant where $p<0.001$; Variables are statistically significant where $p<0.05$.

	Model 1 (n=693)		Model 2 (n=285)	
Model significance	<0.001		<0.001	
	p-value	OR (95% CI)	p-value	OR (95% CI)
Aircraft noise level (DNL) (OR per dBA)	**<0.05**	**1.129** (1.091-1.169)	**<0.05**	**1.073** (1.012-1.138)
Perceived change in noise	--	--	**<0.05**	**0.499** (0.369-0.675)
Future expectations for noise	--	--	0.303	1.252 (0.816-1.921)
Habituation to noise	--	--	**<0.05**	**0.295** (0.128-0.683)
Feeling of unfairness	--	--	**<0.05**	**1.981** (1.367-2.869)
Attitudes towards airport authorities	--	--	0.257	1.257 (0.846-1.866)
Attitudes towards noise and source	--	--	0.137	0.583 (0.286-1.187)
Self-reported noise sensitivity	--	--	**<0.05**	**2.027** (1.376-2.987)
Coping capacity (feeling helpless)	--	--	0.058	0.431 (0.181-1.029)

aircraft noise. This finding can be used in the prediction of annoyance for residents contemplating a move to an aircraft noise impacted community. As traffic noise affects many more people daily, more individuals can recollect this experience. Those who report being highly annoyed by traffic noise will likely be severely annoyed by aircraft noise as well. Traffic noise annoyance can therefore become a proxy metric for aircraft noise annoyance to help an individual determine the likelihood that they will be severely annoyed in an aircraft-noise-affected neighbourhood.

Respondents were also asked to indicate their levels of annoyance prior to COVID 19 travel restrictions, as this would evoke a recollection of higher air traffic volumes. It was determined that 44% of those that indicated being HA prior to COVID 19 restrictions were now reporting being NON-HA, likely due to the significant reduction in traffic. From the 465 that were NON-HA prior to COVID 19 restrictions, 15 identified becoming HA in the past year. It is hypothesized that these newly HA respondents might have become so due to condensed flight paths or as a result of a higher presence at home due to the pandemic lockdown.

In the questions that were used to compute a misfeasance with source authorities score, the biggest concern for both HA and NON-HA was the unfair distribution of noise. This sentiment has also been consistently expressed by community members around the airport. While many authorities believe that narrowing flightpaths through required navigation performance (RNP) will result in reduced noise impacts, this measure can increase the feeling of unfair distribution of noise, and therefore evoke higher levels of severe annoyance, albeit in a smaller portion of the population. This is not to say that PBN is not an effective measure to reduce aviation's environmental impacts, however it should be expected that severe annoyance will increase for some which will require active management.

In the question that was used to devise an attitude towards the noise and source score, the most notable findings were that HA respondents were much more likely to believe that aircraft noise affects their mental health (83%) versus NON-HA (31%); that aircraft noise affects their physical health (75%) versus NON-HA (27%); that aircraft noise makes their homes less valuable (83%) versus NON-HA (41%). Studies by health and real-estate authorities could be performed to address these concerns, and in way of that possibly mitigate severe annoyance. Across all questions about attitudes towards the noise and source, HA tended to have a more negative stance than NON-HA. Even the belief that 'air travel contributed to the spread of COVID 19' was more strongly professed by HA (79%) than NON-HA (56%). The direction of causality for these attitudes is unknown.

Regarding the question that sought to evaluate the attributes of the noise/source that were most annoying to the respondent, both HA and NON-HA ranked noise level (how loud the aircraft is) as the most disturbing factor, followed by the number of aircraft then the time of the flights for HA and the time of flights followed by the number of aircraft for NON-HA.

When asked about the activities affected by aircraft noise, both HA and NON-HA ranked conversations and outdoor activities as most affected, followed by sleeping patterns. This points to the possibility of relatively low aircraft noise events (around and slightly above the level of speech), being obtrusive or disruptive and possibly evoking high levels of annoyance. This finding might also encourage a broader vocabulary for communicating noise conditions. The use of relational metrics such as the number above (NA) a given noise level (for example interference of speech at 3

meters apart) might improve the understanding of acoustic impacts in a given area. For instance, if someone was told that an address was subject to an average noise exposure level of DNL 55 dBA, this description might not be understood. Conversely, if they were told that while outdoors in the evening, they might expect their conversation to be impaired or disrupted 6 times within an hour on average, this will likely be more relatable.

When asked about the actions taken in response to the disturbance, most HA respondents identified closing windows and doors, feeling helpless / not being able to escape the noise, avoiding the outdoors, and considering moving to a quieter neighbourhood respectively. NON-HA report closing doors and windows, moving to a quieter space, and avoiding the outdoors respectively. The largest discrepancy in answers between HA and NON-HA was reflected in the feeling of helplessness/not being able to escape the noise (HA – 82%, NON-HA – 35%), and the consideration of moving to a quieter neighbourhood (HA – 68%, NON-HA – 24%). The feeling of helplessness has previously been observed in other studies that link exposure to aircraft noise to mental health challenges like depression [17]. This finding can inform possible annoyance mitigation strategies that aim to enhance a community's coping capacity through measures such as voluntary home purchasing, relocation programs, an effective noise complaint process and collaborative decision-making that will help individuals feel empowered and able to affect change.

Another question examined the times that aircraft noise was most disturbing / annoying. Respondents identified being most annoyed in the summer, followed by spring, fall and winter. As for the time of day, most annoying were nights followed by evening, days, and mornings. Respondents also reported being more annoyed on the weekends than weekdays. This can possibly inform aircraft noise metrics and/or how authorities schedule things like runway maintenance, operations etc.

Lastly, when asked about complaint behaviour 83% of HA and 93% of NON-HA reported never having submitted a noise complaint. These are important statistics as they highlight the common misconception that equates complaints to severe annoyance and vice versa.

3.4 Study notes

This study was done in the spring of 2021, amidst COVID 19 travel restrictions. During this period, many residents possibly had a greater 'at home' presence. These exceptional conditions could have uniquely impacted the results of the SONICC survey, although this condition may persist as more companies are offering the work from home option to their employees. In addition, the survey was executed around a single airport. A larger cross-sectional Canadian survey upon the return of pre-pandemic traffic is warranted which might result in the identification of additional acoustic and non-acoustic contributors to severe annoyance.

4 Conclusion

The analysis in this paper highlights the contribution of non-acoustic factors to the study of aircraft noise annoyance. While the presence of noise was found to be a clear qualifier for noise-induced annoyance, personal, situational, and attitudinal variables identified in SONICC were also associated with severe annoyance. Non-acoustic variables such as habituation to noise, feeling of unfairness, and noise sensitivity, were all found to be more predictive of severe annoyance than noise exposure levels. Due to the subjective nature of such non-acoustic variables, they are rarely integrated into policy, guidelines, or discussions with stakeholders. This leads to the erroneous belief that noise perception and annoyance can be predicted with categorical, overgeneralized dose-response type scales. While this type of guidance may be necessary for land-use planning purposes, it should not be viewed in isolation, nor should it be the go-to method for potential residents to assess how much annoyance they will experience in a particular aircraft affected area.

Authorities, law makers, community members and other stakeholders alike can benefit from understanding public sentiment about noise and all factors that play a role in noise annoyance. This type of knowledge may inform everything from airport operations and planning (i.e., time of day and flight path distribution), mitigation efforts (i.e., increasing coping capacity for affected communities), community outreach (i.e., providing more holistic information and guidance as to the effects of various acoustic and non-acoustic factors on annoyance) and even policy (i.e., including clauses about all levels of aircraft noise exposure in real-estate transactions). Disregarding the contributions of non-acoustic factors in severe annoyance may leave authorities with few mitigation options, other than striving for marginal reductions in noise exposure which are often not reflected in community perception and annoyance outcomes. Alternatively, managing noise exposure as well as non-acoustic factors allows for a multi-pronged approach for mitigating the effects of aircraft noise on communities.

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