DOI: 10.61782/fa.2023.0491

forum acusticum 2023

IMPACT SOUND AROUND THE WORLD – AN ONLINE LISTENING SURVEY ABOUT THE PERCEIVED ANNOYANCE DUE TO IMPACT SOUNDS

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ABSTRACT

To support a potential introduction of an impact sound requirement into the National Building Code of Canada, the National Research Council of Canada has initiated several research projects. One of these projects consisted of several laboratory listening experiments regarding the perceived annoyance due to impact sounds. As an alternative to the typical laboratory-based listening experiments, an online-based listening survey was published for world-wide access, from November 2022 to March 2023, enabling data collection across a diverse target audience in many parts of the world. The ability to collect data with an online survey allows to reach the general public much more than with any laboratory-based experiment, and it is especially relevant in the context of the Covid-19 pandemic, which has forced researchers to re-evaluate in-person procedures. In this paper, the online listening survey is presented and the results are discussed in relationship to the results of the laboratory tests that were carried out in Canada, Korea and Germany. Additional data that is collected in the online survey, such as the country of residence and type of housing, is used to explore the moderating effects on the annoyance ratings.

Keywords: *residential buildings, impact sound, online survey*

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1. INTRODUCTION

The National Research Council of Canada (NRC) has determined the topic of impact sound transmission in multi-unit residential buildings as one of its focus areas of investigation. Several long-term research projects have been initiated in this context, in part with the goal to support a potential addition of an impact sound requirement into one of the next editions of the National Building Code of Canada (NBC). For such a building code requirement to fulfill its purpose of minimizing the effect of transmitted noise on the building residents it is crucial to connect the perceived annoyance by building occupants to standardized measurements of impact sound transmission according to ASTM E492 [1] and ISO 10140-3 [2]. This is the aim of the present study.

The initial studies on the perceived annoyance due to impact sound were based in the laboratory and carried out in collaboration with partners in Korea and Germany, and the methodology and preliminary results have been reported previously [3]. During and after the lock-downs due to the Covid-19 pandemic and considering the associated restrictions for in-person studies the development of a web-based interface was started to explore the possibility of engaging with the general public and thus also expanding the reach of the study.

For a pilot test the first version of the online listening survey was published on the internal network of the NRC and the results of the pilot test, which were very promising, have been reported [4]. The final version of the online listening survey was published on an externally-facing web-server hosted at the NRC, and was accessible to the public from November, 2022, to the end of March, 2023. In this paper the setup and preliminary results of this public version of the survey are reported.

In Sec. 2 the survey interface and procedure is described, including the post-survey questionnaire, which is used to gather additional information separately from the actual listening task. The preliminary results are reported in Sec. 3 and compared to the results of previous laboratory studies that used the same recordings. The findings are summarized in Sec. 4 and an outlook for future work is given.

2. ONLINE SURVEY

The user interface for the online listening survey was adapted from the BeaqleJS framework for browser-based listening tests, which is written in HTML5 and JavaScript [5]. The test type was a MUSHRA (Multiple Stimuli with Hidden Reference and Anchor) test, although no explicit reference was given for this study. The technical modifications to the interface have been described in [4].

The recorded samples for the online listening survey were the same as previously used for the laboratory studies. Samples from 12 different assemblies using five different impact sources were used. The assemblies were either based on wood-joist or Cross-Laminated Timber (CLT) construction. The five impact sources were the standardized impact rubber ball, dropped from 0.1 m and 1 m, walkers with and without shoes, and individual drops of the hammers of the standardized tapping machine.

The survey interface was available in both English and French. Access to the survey was obtained through separate links, one for the English version and one for the French version. The survey responses were saved on a secure web-server located at the NRC, and no information (such as IP address) that could relate the responses to the participants was recorded. After an introductory text that explained the study background, eligibility to participate as well as instructions, the first step in the survey was the output level adjustment, which is explained in the next section.

2.1 Output level calibration

Opposed to the laboratory situation, one of the factors that cannot be fully controlled in such an online listening experiment is the output level at the participant's device. For the rating of absolute annoyance – in contrast to relative annoyance where two recordings are compared – the knowledge about the Sound Pressure Level (SPL) at the listener's ears is desirable.

To achieve at least an approximate calibration of output level, the following approach was chosen (see Fig. 1): the participants were asked to play a reference signal and then adjust their output level until they could barely hear the test tone. The reference signal was a 1 kHz tone and the amplitude was scaled in such a way that it corresponded to an SPL of 20 dB when played without adjustment using calibrated equipment.

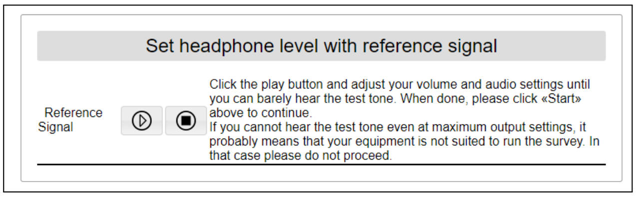

Figure 1. Online survey user interface: output level calibration

To estimate the effect of this calibration approach, test participants in Korea performed the listening survey in the laboratory under the same conditions and with the same equipment that was previously used for the controlled and calibrated study there. The comparison of the results between the calibrated study and the online survey interface are presented in Sec. 3.2.

2.2 Rating procedure

After the output level calibration was completed, the participants began the rating procedure. The rating interface is shown in Fig. 2.

On each page of a total set of 14 pages, five recorded samples were presented. The participants were able to switch between the pages and play the samples as many times as they liked. The number of visits to each page and the number of plays for each sample were recorded by the software. The participants were asked to rate the annoyance of each sample using a slider that could be freely moved between the end points, which represented ratings of ”not annoying” and ”very annoying”, respectively. The slider values were recorded as values between 0 and 100.

2.3 Post-survey questionnaire

After the samples on all 14 pages had been rated the participants were asked to fill out a questionnaire to obtain additional information. A screenshot of the questionnaire can be seen in Fig. 3).

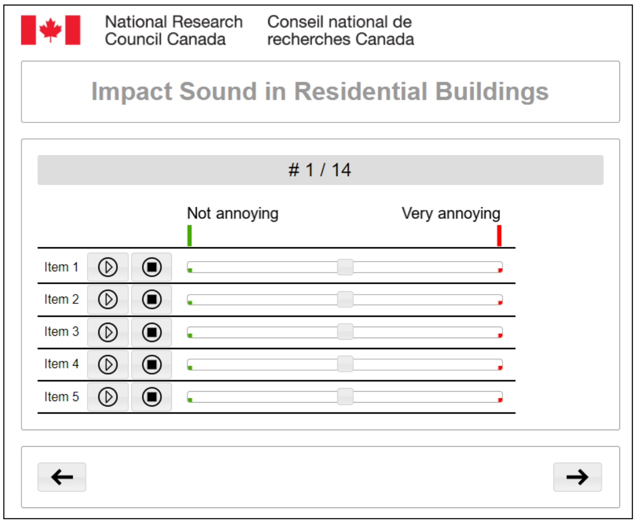

Figure 2. Online survey user interface: rating procedure

The questionnaire contained sections on the following topics:

- the participant's country of residence, age, gender, and whether they had hearing loss
- the headphones they used for the survey, and what their experience with the survey was
- their housing situation and their experience with noise inside their place of residence
- the 21 questions of the Weinstein noise sensitivity questionnaire [6]

3. RESULTS

A total of 359 survey responses from 36 different countries were received between November, 2022, and the end of March, 2023. This includes 54 responses from the laboratory in Korea that were used to validate the output calibration procedure.

3.1 Participant information

In Fig. 4, a histogram of responses by country is shown, where for a compact presentation the responses for the EU member states have been grouped. A significant number ($\geq$ 20) of responses was only received from the following countries: Canada (59), France (20), Germany (28),

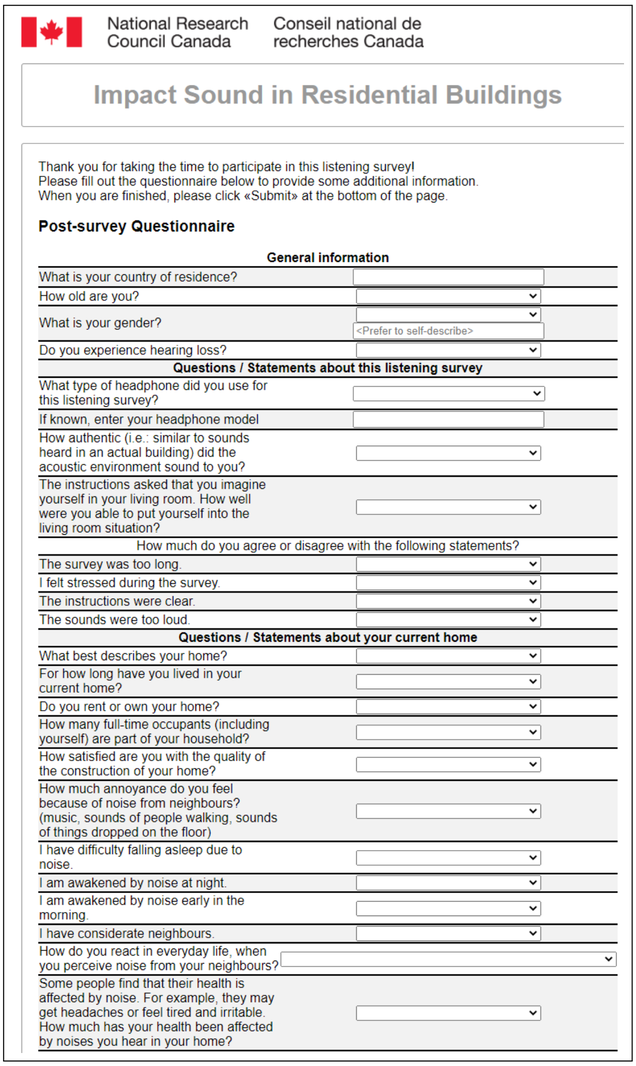

Figure 3. Online survey user interface: post-survey questionnaire (without the Weinstein noise sensitivity questions)

Korea (54), UK (84) and USA (40). It would thus be possible to compare the responses in these countries between each other to potentially gain an insight into cross-cultural effects, for example. This will be explored in the future.

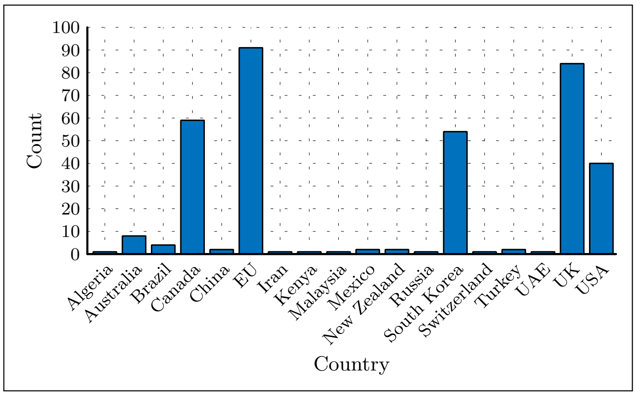

Figure 4. Histogram of responses by country. Responses from the EU member states have been grouped.

Fig. 5 shows the distribution of the participants' age in steps of 10 years (15-24, 25-34, etc.). There is a relatively even distribution with a maximum in the age group of 25-34 years. Since one of the groups of interest for this study is the elderly population it is good to see a decent number of responses in the age ranges above 55 years.

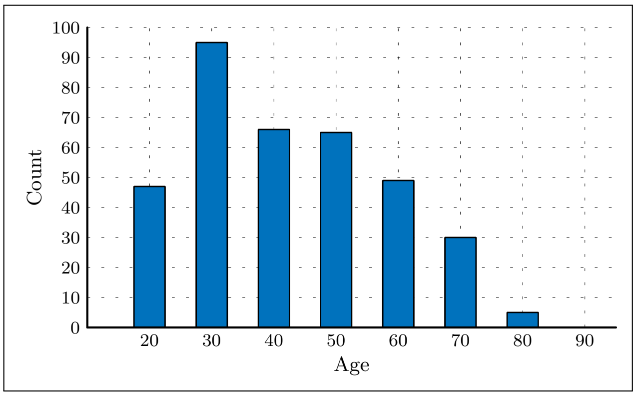

Figure 5. Histogram of responses by age.

Finally, a histogram of the Weinstein noise sensitivity scores is presented in Fig. 6 in steps of 10 (15-24, 25-34, etc.). The minimum possible value is 21 whereas the maximum possible value is 126. The data indicates that most participants would be considered noise-sensitive. In Weinstein's original work, the averages for the noise-insensitive and noise-sensitive groups were 40 and 68, respectively. The results from this study contain essentially no results below 45. It could be hypothesized that those who are more noise-sensitive tend to be more interested in these types of surveys but that will have to be explored in the future.

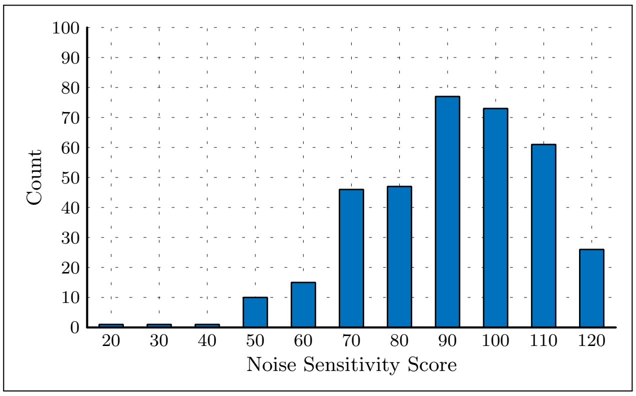

Figure 6. Histogram of the Weinstein noise sensitivity scores.

3.2 Validation of output level calibration

As discussed in Sec. 2.1, a validation study was carried out to determine the effect of the calibration approach using a reference tone with low SPL. To present the comparison between the results from the calibrated laboratory study ($N = 30$ participants) and the results from the laboratory study with the online survey interface ($N = 54$), the average annoyance rating is plotted as a function of the total loudness level of the recorded samples in phon (as determined in the laboratory) in Fig. 7.

To highlight the data trends, a curve-fit with a sigmoid function scaled to cover the range from 0 to 100,

$$y(x, x_0, k) = \frac{100}{1 + \mathrm{e}^{-\frac{k}{25}(x - x_0)}}, \tag{1}$$

is performed for each set of data, and the result is displayed in the graphs as a dashed line. In Eqn. (1), x_0 is the center value along the x-direction and k determines the slope of the curve around x_0. In the graphs, the value of the coefficient of determination (R^2) is also indicated as a measure of the goodness-of-fit.

The comparison between the laboratory results using calibrated equipment and the laboratory results using the

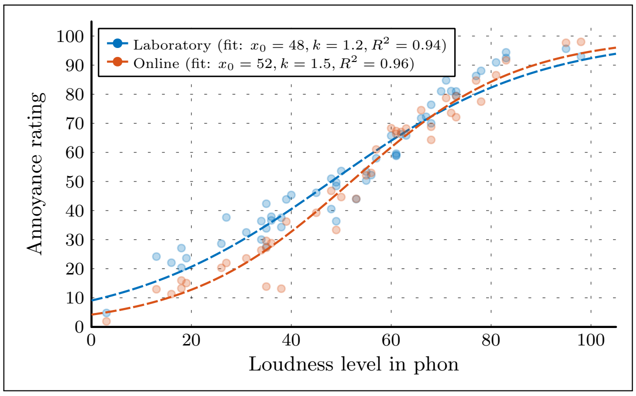

Figure 7. Average annoyance rating as a function of total loudness in phon for the results from Korea for both the calibrated laboratory study (”Laboratory”) and the laboratory study using the online survey interface (”Online”).

online survey interface reveals that the data is remarkably similar for samples with a loudness of 50 phon and above. At lower loudness values, the results using the online survey interface are lower by about 10 points on average. The explanation for this is that the background noise levels were higher (by approximately 10 dB(A)) during the tests using the online survey interface. With higher background noise levels, some of the samples with lower loudness levels were no longer audible and hence were rated with lower annoyance scores. Considering that the uncertainty of the laboratory responses with the calibrated equipment and the laboratory responses using the online survey interface are about ± 6 points and ± 5 points, respectively, it can be concluded that the output level calibration worked well and does not seem to introduce a significant bias into the results.

3.3 Correlation with standardized metrics

One of the objectives of this work is to determine how well the standardized measurements of impact sound transmission in the laboratory correlate with the annoyance as it is perceived by the building occupants. In part, the results of the online listening survey serve to validate the results obtained in the laboratory.

The determination of the correlation between the standardized measurement data and the survey results is achieved through a fit of the sigmoid function in Eqn. (1) to the average annoyance ratings as a function of different single number ratings obtained from the standardized measurements. For a compact overview of the data, only the determination coefficients of the sigmoid fits are presented here.

As an example, Fig. 8 shows the comparison of the determination coefficients between the laboratory study and the online survey for the sigmoid fit of the average annoyance rating as a function of values of $L_{n,w} + C_{I,50-2500}$ according to ISO 717-2 [7]. The laboratory results are the average of five different studies carried out in Canada, Korea and Germany and the online survey results have been averaged across responses from the same three countries.

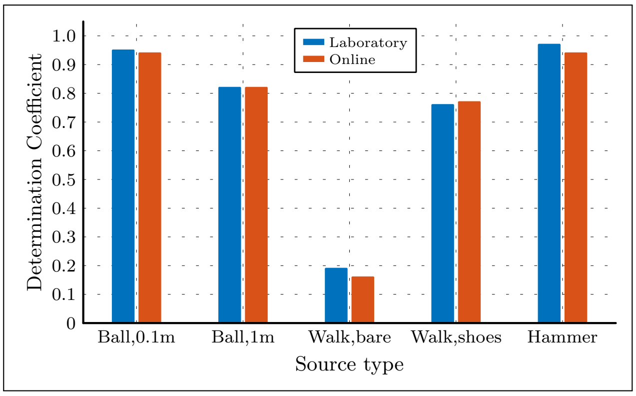

Figure 8. Comparison of determination coefficients between laboratory study and online survey for sigmoid fit of average annoyance rating as a function of values of $L_{n,w} + C_{I,50-2500}$ for five different impact sources.

In the figure there are five different groups of bars, one for each of the five impact sources that are considered in this study. It can be seen that the results of the laboratory study and the online survey agree very well. The minor differences seen for some of the impact sources are not statistically significant.

4. CONCLUSIONS

In this paper, an online listening survey regarding the annoyance caused by impact noise in residential buildings has been described and put into context with previous laboratory studies. The survey setup, rating procedure and a post-survey questionnaire were described in detail.

For the 359 responses that were received, histograms of the country of residence, age and Weinstein noise sensitivity score were presented. Further information, such as housing type and length, was recorded in the post-survey questionnaire but not presented here for the sake of brevity. A more detailed evaluation of the additional information that was gathered will be presented in the future.

The effect of the approach of output level calibration with a reference tone at a low SPL was investigated through a comparison between results from a calibrated study and the results using the online survey interface, both carried out under the same conditions. A very good agreement between the two data sets was observed and hence it was concluded that the output level calibration did not seem to introduce a significant bias into the results.

A comparison of the correlation between the annoyance ratings and single number metrics from standardized measurements between previous result from laboratory studies and the online survey showed very similar values, simultaneously confirming the results of the laboratory studies as well as the approach of using an online listening experiment. It has to be emphasized that the good agreement between the laboratory and online results may be particular to the types of sounds of interest in this study, which are short and impulsive and tend to easily grab the attention of the listener, independent of the listening environment. Whether the approach of using an online survey for other types of sounds and other study designs is also valid has to be evaluated on a case by case basis.

The online listening survey has generated a lot of useful information that will be evaluated in more detail in the future. Possible aspects that will be covered are the differences of annoyance ratings between countries and how for example the type and length of housing may affect the annoyance ratings.

5. ACKNOWLEDGMENTS

The authors would like to gratefully acknowledge the following people who contributed to the success of this work: Anca Galasiu and the LVQ team at the NRC's Construction Research Centre for hosting the survey interface and graciously responding to the many requests for an update on the responses, Vanessa Miceli and the NRC Communications team for reviewing and promoting the survey, Ashley Piccone and the media team of the American Institute of Physics for inviting the authors to highlight the study at the press conference at the 183rd meeting of the Acoustical Society of America in Nashville, and all of the participants of this study who donated their time and helped provide valuable data.

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