Multi-cultural perception of impact sound: an international online listening survey about the perceived annoyance due to impact sounds

Batista Da Cunha, Iara; Skoda, Sabrina; Mueller-Trapet, Markus; Choi, Young-Ji; Mahn, Jeffrey

Publisher's version / Version de l'éditeur:
https://doi.org/10.3397/IN_2023_0833
INTER-NOISE and NOISE-CON Congress and Conference Proceedings, InterNoise23, INTER-NOISE and NOISE-CON Congress and Conference Proceedings, 6, pp. 5824-5832, 2023

inter·noise 2023
CHIBA,GREATER TOKYO 20-23 AUGUST

Multi-cultural perception of impact sound -- An international online listening survey about the perceived annoyance due to impact sounds

Iara Batista da Cunha[1]
National Research Council Canada (NRC)
1200 Montreal Road, M27, Ottawa, Ontario K1A 0R6, Canada

Sabrina Skoda[2]
National Research Council Canada (NRC)
1200 Montreal Road, M27, Ottawa, Ontario K1A 0R6, Canada

Markus Müller-Trapet[3]
National Research Council Canada (NRC)
1200 Montreal Road, M27, Ottawa, Ontario K1A 0R6, Canada

Young-Ji Choi[4]
Kangwon National University
1 Kangwondaehak-gil, Chuncheon-si, Gangwon-do, 24341, Republic of Korea

Jeffrey Mahn[5]
National Research Council Canada (NRC)
1200 Montreal Road, M27, Ottawa, Ontario K1A 0R6, Canada

ABSTRACT

To support the introduction of requirements for protection from impact noise in the National Building Code of Canada, the National Research Council of Canada implemented pilot subjective evaluations of impact sounds to evaluate the best metric to be used in the Code. As an alternative to the typical laboratory-based listening experiments, online-based listening tests were used. 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 was especially relevant in the context of the Covid-19 pandemic, which forced researchers to re-evaluate in-person procedures. This online listening survey was published for world-wide access, enabling data collection across a diverse target audience in many parts of the world. The survey and its preliminary results are presented and discussed in this paper. Data collected as part of the online survey, such as the person's country of residence and the type of dwelling they lived in, is used to explore the multicultural effects on the annoyance ratings.

[1] Iara.BatistaDaCunha@nrc-cnrc.gc.ca
[2] Sabrina.Skoda@nrc-cnrc.gc.ca
[3] Markus.Mueller-Trapet@nrc-cnrc.gc.ca
[4] youngjichoi@kangwon.ac.kr
[5] Jeffrey.Mahn@nrc-cnrc.gc.ca

1. INTRODUCTION

To support a code change request to implement impact noise requirements for dwellings in the National Building Code of Canada (NBCC), The National Research Council of Canada (NRC) has initiated several long term research projects. Acoustic requirements in building codes have the main purpose of minimizing the detrimental effect of transmitted noise on the building residents. For that, it is necessary to connect objective measurement results for the performance of sound insulation in buildings, such as ASTM E492 [1] and ISO 10140-3 [2], to perceived annoyance by building occupants.

Considerable objective data has been collected for different Canadian construction types [3-6], however, more subjective data to match the measurements is required. This set of data is crucial in ensuring that the requirements in the building codes lead to an acoustic performance that is perceived to be satisfactory by the building occupants. The present paper is part of a study with a focus on acquiring this type of data and establishing a relationship between the subjective perception and the performance of sound insulation in buildings.

Initial studies on the perceived annoyance due to impact sound were based on laboratory listening tests and carried out in Canada in collaboration with partners in Korea and Germany, with preliminary results reported in [7]. With the COVID-19 pandemic crisis and lock-downs around the world, restrictions associated with in-person studies led to the development of a web-based interface to perform the subjective tests. This not only permitted to reach the general public during the in-person restrictions but also expanded the reach of the study to a broader population. With promising results from a pilot test [8], carried out on the NRC internal network, a final version of the online listening survey was published and accessible to the public between November 2022 and March 2023. This survey reached not only the population of the countries who initially collaborated in this study, but was accessed by participants from many different countries.

This paper presents the test setup and preliminary results as well as an initial analysis of cross-cultural perception of impact sound. For this purpose, annoyance ratings are compared among different countries, and results are discussed within the scope of participants' housing situation and self-reported strategies to cope with noise from neighbors.

2. ONLINE SURVEY

The online listening was designed as a MUSHRA (Multiple Stimuli with Hidden Reference and Anchor) test and had its user interface adapted from the BeaqleJS (browser based evaluation of audio quality and comparative listening environment) framework for browser-based listening tests, which is written in HTML5 and JavaScript [9]. The technical modifications to the interface have been described in [8]. 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.

The survey interface was available in both English and French, with access obtained through separate links: one for the English version and one for the French version. 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, followed by the listening test itself.

2.1. Output level calibration

In the laboratory situation, it is possible to ensure that the output sound levels are equally calibrated for all participants. However, this is not true for an online experiment, as the output level at the participant’s device cannot be fully controlled. Especially in the case of this study, which relates to 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 Figure 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.

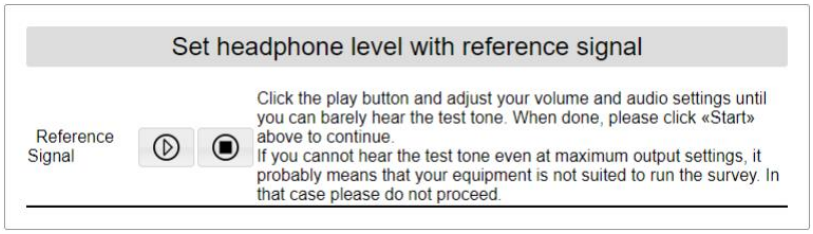


Figure 1: Online survey user interface – output level calibration

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 discussion of these tests can be found in [10].

2.2. Rating procedure

After the output level calibration was completed, the participants began the rating procedure. Fifty-four different impact sounds were presented to the participants to be rated in terms of annoyance. The impact sounds resulted from five different impact sources (ball drops from 0.1m and 1m height, walking with socks and shoes and hammer drops), operated on twelve different floor-ceiling configurations, combining either a cross-laminated timber (CLT) base element or a subfloor of oriented strand board (OSB) and engineered I-joists with various ceiling and topping materials.

The survey consisted in a total of fourteen pages, where each page presented five recorded samples. 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 for future analysis. 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 from left to right. The slider values were recorded as values between 0 and 100. The rating interface is shown in Figure 2.

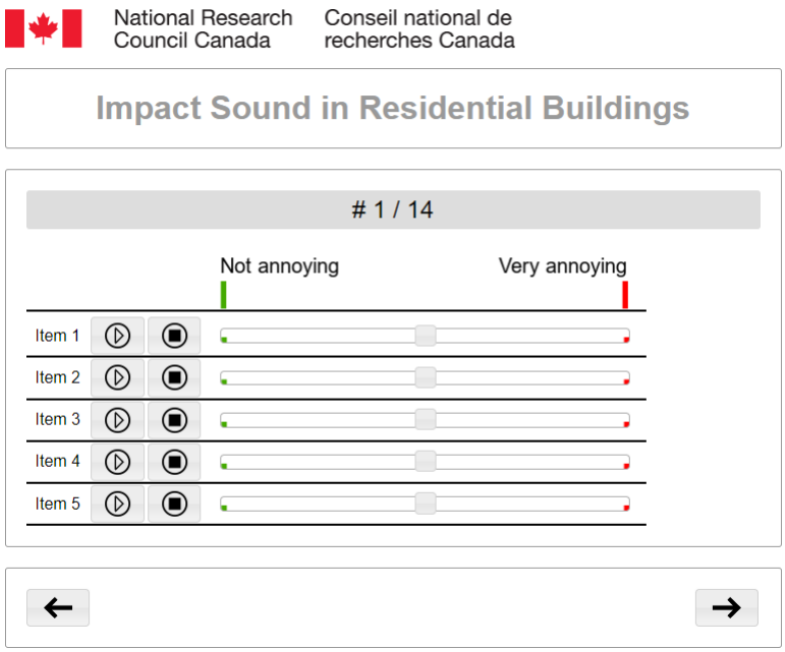


Figure 2: Online survey user interface – rating procedure

2.3. Post-survey questionnaire

After rating the samples on all 14 pages, the participants were asked to fill out a questionnaire to obtain additional information, specifically:

- their 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
- their coping strategies towards noise from neighbors
- the 21 questions of the Weinstein noise sensitivity questionnaire [11]

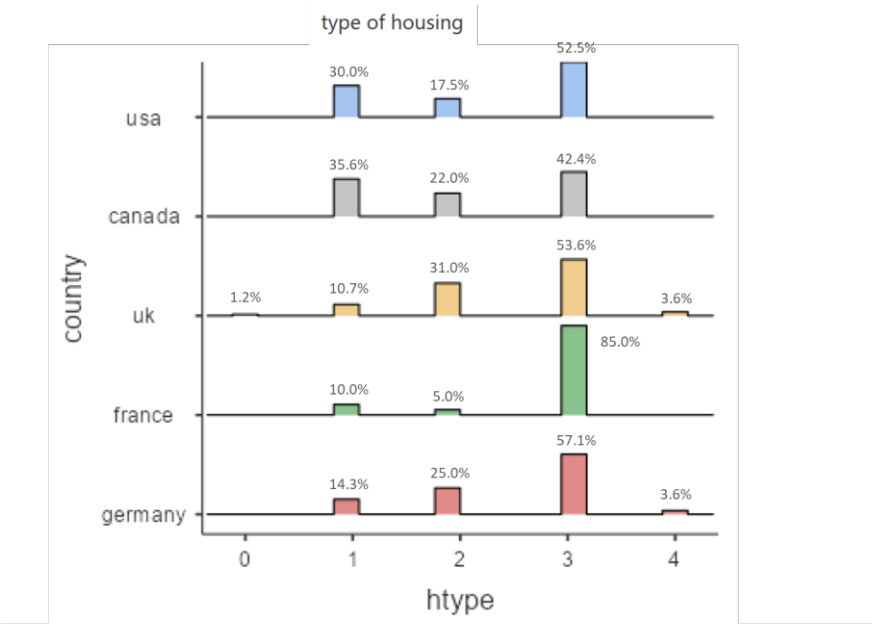
3. RESULTS

In total, the survey had 359 responses from 36 different countries. The most significant numbers of responses (≥ 20) were received from the following countries: Canada (59), France (20), Germany (28), Korea (54), UK (84) and USA (40). The results in Korea were collected in a laboratory environment, which may limit the comparability with the results from participants who performed the online study in their home environments. Thus, the dataset from Korea was excluded in the following analyses and from here on the focus of this paper will be in comparing the responses from the five countries Canada, France, Germany, UK and USA.

Statistical data analysis was performed using the Jamovi 2.3.21 software [12]. Linear mixed-effects models were calculated including a random intercept for each participant and using restricted maximum likelihood estimates of variance components and Type III Analysis of Variance via Satterthwaite's degrees of freedom method. A one-way analysis of variance (ANOVA) was used to evaluate differences between countries. For all analyses, the significance level α was set to .05.

3.1. Type of housing and length of residence

The housing profile of the participants in this study revealed to be similar among the five countries. The majority of respondents from all countries indicated to live in apartments, followed by detached houses in both USA and Canada and semi-detached units in both UK and Germany. A similarity was also found in the period of residence, with most respondents for all countries indicating five or more years spent in the current housing. The distribution of house types and length of residence are plotted respectively in Figure 3 and Figure 4.



0: no data, 1: detached house, 2: semi-detached house, 3: apartment, 4: other

Figure 3: Participants' housing type profiles per country

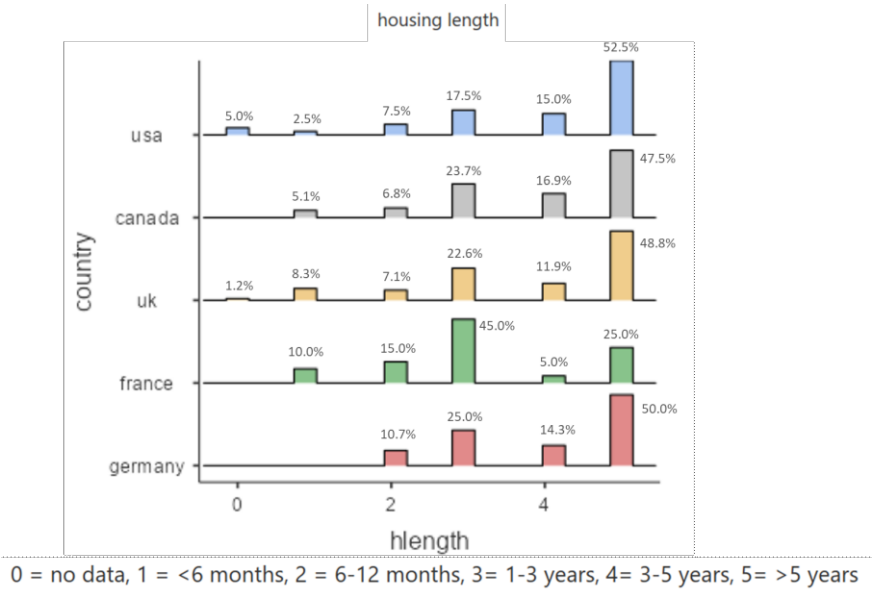


Figure 4: Participants' period of residence per country

3.2. Coping strategies

Coping strategies as a way to deal with perceived noise from neighbors seem to differ slightly among countries. While most participants in North America and the UK seem to prefer masking noise with other sounds (e.g., music), in France and Germany the proportion of participants who do nothing but feel disturbed by the noise is higher. A third group of participants reported doing nothing while not being disturbed by the noise. Escaping the noise was selected only by few participants, mostly in Canada and the UK. The proportion of participants trying to actively stop the noise is similar among countries, with a slightly higher number in France. Figure 5 shows the distribution of coping strategies per country.

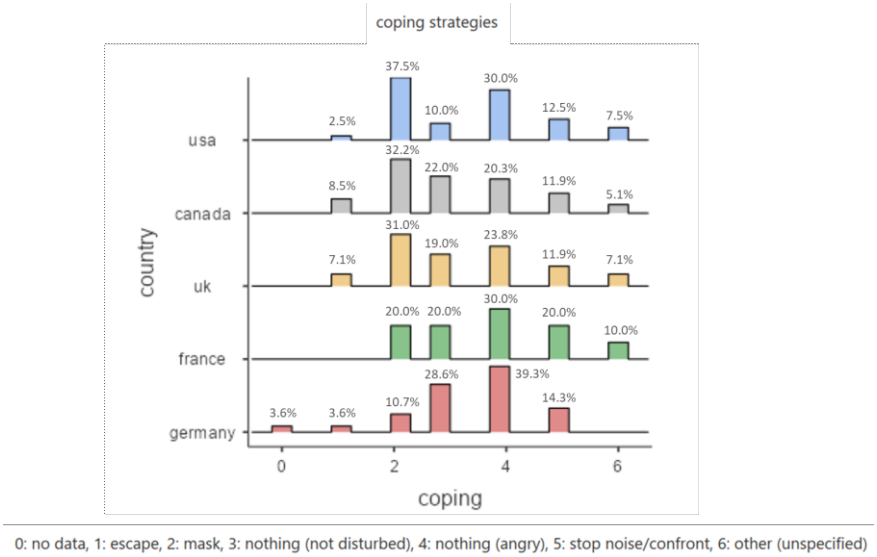


Figure 5: Participants coping strategies per country

3.3. Intraclass correlation coefficient/Effect of person-related differences

To investigate the effect of participants' person-related differences on the annoyance ratings, a linear mixed-effects model (LMM) was calculated, using only one random intercept for each participant. This so called null-model yields the intraclass correlation coefficient (ICC), which is a measure of the amount of variance in subjective annoyance ratings that is only explained by the participants, without considering effects of systematic variations in the experiment. The model result shows that individual differences among participants explain 22.2% of variance in annoyance ratings in this study (ICC = .222), not taking into account the effects of the different sound sources or floor-ceiling assemblies yet. These two variables were included in the model in the next step.

3.4. Annoyance ratings by country

To evaluate multicultural aspects of annoyance perception, potential differences in annoyance ratings based on the participants' country of residence were investigated. In previous laboratory experiments [7, 13], different annoyance levels had been observed for the same impact sounds between datasets from Canada, Korea and Germany. To see if these differences in annoyance can also be observed in the online experiment, the participants' responses were grouped by country of residence. To maintain statistical power, only the datasets from the previously mentioned countries with more than twenty responses were included in this analysis.

A linear mixed model was calculated with one random intercept for each participant, and three independent fixed factors: the variables 'impact source', 'floor-ceiling assembly' and 'country'. This model, explaining 66% of variance in subjective annoyance ratings ($R^2_{cond.} = .658$), confirms an effect of the participants' country of residence on the subjective annoyance ratings. The LMM yields three statistically significant main effects on the annoyance ratings: 'impact source' ($F(4,12212) = 1999.71$, $p < .01$), 'floor-ceiling assembly' ($F(11,12212) = 454.62$, $p < .01$) and 'country' ($F(4,227) = 2.91$, $p = .022$).

Figure 6 shows the mean annoyance ratings for each of the five different impact sources. Ratings are averaged across participants and floor-ceiling assemblies for each impact source. For each country, results are depicted with a separate line.

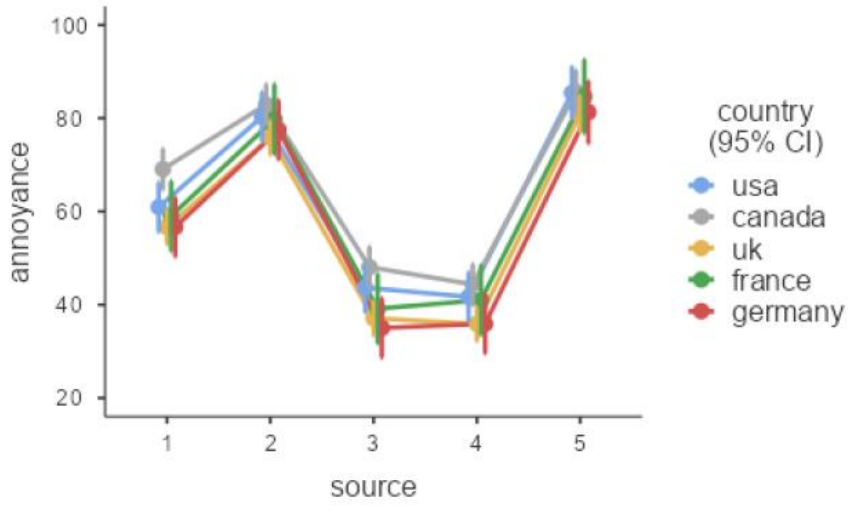


Figure 6: Average annoyance ratings for each impact source – separated by country

Annoyance ratings of the five different impact sources cover a wide range on the rating scale, with ball drops from 1m height and the hammer drops rated as most annoying, followed by the ball drops from 0.1m height. The two types of walking sounds (socks and shoes) were rated as almost

similar and least annoying in this study. This reflects the findings previously obtained in laboratory experiments with the same sound stimuli.

The figure also shows that participants in all countries basically agreed on the highest annoyance ratings for the ball drops from 1m and the hammer drops with values close to the maximum scale level of 100. In contrast, the ratings of the two types of walking sounds and of the ball drops from 0.1m height, which were all rated lower in annoyance, show a higher spread of values, where different annoyance ratings among countries become more visible.

The data suggests that participants agree on the same annoyance ranking of the five impact sources, which is also in line with previous laboratory experiments. However, the absolute annoyance levels differ between countries. The highest annoyance levels for all five impact sources were reported in Canada, and the lowest annoyance ratings were obtained in Germany. The difference in ratings between these two countries is about 20 scale points. Results from USA, UK and France range in between, with USA close to results from Canada and the UK results almost similar with Germany. In post-hoc comparisons, only the differences between Canada and Germany, as well as between Canada and the UK, reach the level of statistical significance.

The same was observed when comparing the annoyance ratings averaged for each of the twelve floor-ceiling assemblies among countries. The annoyance ranking of the twelve assemblies was reported similarly by all participants, however, the absolute annoyance levels were different among countries.

3.5. Regional differences between North America and Europe

The observed differences in mean annoyance ratings among countries showed a tendency towards forming two regions of interest: North America and Europe. Therefore, in the next step, the datasets from Canada and USA were combined to one dataset representing North America, and the datasets from France, UK and Germany were merged into one dataset for Europe. A comparison of the two regions showed higher average annoyance ratings in North America, which was also confirmed by a linear mixed model ($R^2_{cond.}$ = .66,), using the variables ‘impact source’, ‘floor-ceiling assembly’ and ‘region’ (instead of country) as independent fixed effects, and again one random intercept for each participant. All three fixed effects were highly significant predictors of subjective annoyance ($p < .01$). The impact sounds in the online study were rated more annoying in North America than in Europe, as shown in Figure 7.

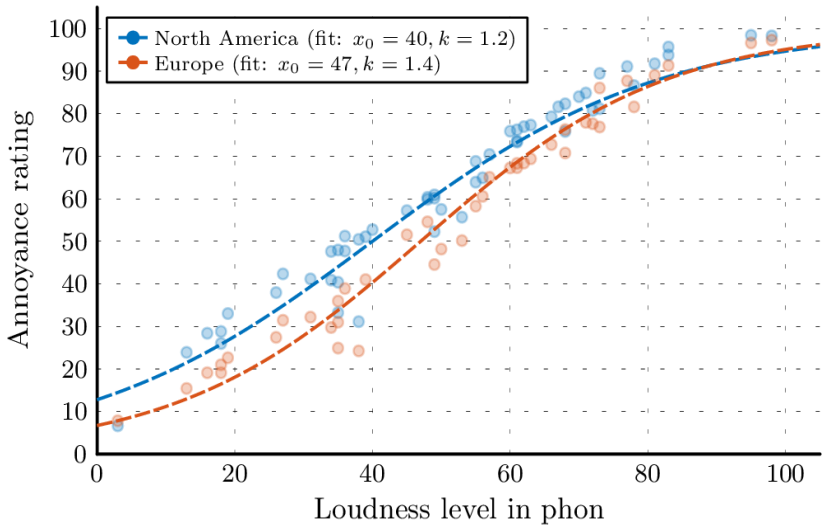


Figure 7: Annoyance ratings as function of loudness level

Figure 7 displays a comparison of the average ratings of all test stimuli depicted as functions of the stimuli loudness levels, with separate curves for North America and Europe. The curves are

sigmoid fit functions to each of the two datasets. Both curves show similar tendency with slightly differing slopes and a shift in x_0 of 7phon. This means people in North America apparently feel more annoyed at a lower loudness level of impact sounds, than people in Europe. Particularly in the loudness range below 50phon, participants in North America gave higher annoyance ratings than in Europe. Towards higher loudness levels the two curves converge, as participants in both regions seem to agree more on high perceived annoyance.

To investigate if the observed rating differences among countries (and regions) could be a result of differences in participant demographics, the independent variables 'age' and 'gender' were included in the analysis. However, the distribution of participants' age and gender was similar in the five countries and also when comparing the two regions North America and Europe. Including the two variables in the LMM yielded no significant main effects of age nor gender on the subjective annoyance ratings. Therefore, the observed offset in perceived annoyance levels between North America and Europe in the online study cannot be attributed to any of these two variables.

4. DISCUSSION AND CONCLUSIONS

Preliminary results from the online study show that annoyance perception differs between participants from different countries and from different regions. Although the rankings between different types of impact sounds were judged in a similar way by participants across the world, the results from the online study show different levels of annoyance reported by participants from different countries. Grouping countries into regions (North America and Europe) makes the effect even more visible and highly statistically significant. Covariates such as age and gender of participants do not explain the observed differences in annoyance ratings. Participants across all countries reported very similar types of housing and periods of residence, nevertheless, an effect of the housing situation on perceived annoyance to impact sounds will be subject of further investigation, as well as the effect of noise sensitivity.

The results from the online study basically reflect well the findings from the previous laboratory studies with regard to perceived annoyance from the different impact sources and floor-ceiling assemblies. However, in contrast to the laboratory studies, where annoyance ratings from Canada and Germany showed no significant differences, the results from the online study, when participants performed the experiment in their own domestic environments, are now significantly different between these two countries, with higher annoyance values in Canada. This suggests an influence of participants' home environment, that will be subject to further investigations. To evaluate multi-cultural perception of impact sounds more in detail, the data collected and with the online study will need to be expanded to allow the inclusion of subjective annoyance evaluations from more countries and regions.

ACKNOWLEDGEMENTS

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 our study at the press conference at the 183rd meeting of the Acoustical Society of America in Nashville; and most importantly all of the participants of this study who donated their time and helped provide valuable data.

REFERENCES

1. "ASTM E492-09(2016): Standard test method for laboratory measurement of impact sound transmission through floor-ceiling assemblies using the tapping machine," 2016.
2. "ISO 10140-3: Acoustics – Laboratory measurement of sound insulation of building elements – Part 3: Measurement of impact sound insulation," 2010.

3. A. C. C. Warnock, J. A. Birta. “Summary Report for Consortium on Fire Resistance and Sound Insulation of Floors: Sound Transmission Class and Impact Insulation Class Results”. Internal Report no. IRC-IR-766, National Research Council of Canada, 1998. https://doi.org/10.4224/20331639
4. A. C. C. Warnock, J. A. Birta. “Detailed report for consortium on fire resistance and sound insulation of floors: sound transmission and impact insulation data in 1/3 octave bands”. Internal Report no. IRC-IR-811, National Research Council of Canada, 2000. https://doi.org/10.4224/20386418
5. A. C. C. Warnock. “Impact sound measurements on floors covered with small patches of resilient materials or floating assemblies”. Internal Report no. IRC-IR- 802, National Research Council of Canada, 2001. https://doi.org/10.4224/20331190
6. A. C. C. Warnock. “Summary report for Consortium on Fire Resistance and Sound Insulation of Floors: sound transmission and impact insulation data”. Research Report no. RR-169, National Research Council of Canada, 2005. https://doi.org/10.4224/20377405
7. M. Müller-Trapet, K. Möller, Y.-J. Choi, and B. Zeitler, “A subjective study of source types and rating methods for impact sounds in buildings,” in INTER-NOISE and NOISE-CON Congress and Conference Proceedings, vol. 261, pp. 1233–1240, 2020.
8. M. Müller-Trapet, I. Batista da Cunha, and J. Mahn, “Subjective studies on impact sound in times of a pandemic – a comparison between a laboratory study and an online listening test,” in INTER-NOISE and NOISE-CON Congress and Conference Proceedings, vol. 263, pp. 5090–5096, 2021.
9. S. Kraft and U. Zölzer, “BeaqleJS: HTML5 and JavaScript based Framework for the Subjective Evaluation of Audio Quality,” in Linux Audio Conference, Karlsruhe, Germany, 2014.
10. M. Müller-Trapet, S. Skoda, Y.-J. Choi, I. Batista da Cunha, J. Mahn. “Impact sound around the world – an online listening survey about the perceived annoyance due to impact sounds” in 10th Convention of the European Acoustics Association, Forum Acusticum, 2023 [Manuscript submitted for publication].
11. N. D. Weinstein, “Individual differences in reactions to noise: a longitudinal study in a college dormitory.,” Journal of Applied Psychology, vol. 63, no. 4, p. 458, 1978.
12. The jamovi project (2022). jamovi (Version 2.3) [Computer Software]. Retrieved from https://www.jamovi.org
13. S. Skoda, M. Müller-Trapet, Y. Choi, I. Batista da Cunha, and J. Mahn, "Annoyance evaluation of impact sounds on timber floors in different listening test setups," in Proceedings of the 24th International Congress on Acoustics, Korea, 2022.