

canadian acoustics

acoustique canadienne

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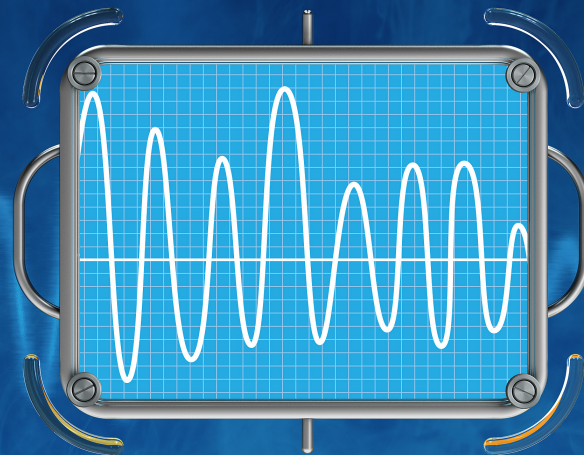
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2020

**Acoustics Week
in Canada**

**Semaine
canadienne
de l'acoustique**



**Actes de la conférence
Conference Proceedings**

 **online event**

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Acoustique canadienne est publiée quatre fois par an, en mars, juin, septembre et décembre. Cette revue trimestrielle est envoyée gratuitement aux membres individuels de l'Association canadienne d'acoustique (ACA) et aux abonnés institutionnels. L'Acoustique canadienne publie des articles arbitrés et des rubriques sur tous les aspects de l'acoustique et des vibrations. Ceci comprend la recherche, les recensions des travaux, les nouvelles, les offres d'emploi, les nouveaux produits, les activités, etc. Les articles concernant les résultats inédits ou les applications de l'acoustique ainsi que les articles de synthèse, les tutoriels et les exposés techniques, en français ou en anglais, sont les bienvenus. L'Association canadienne d'acoustique a sélectionné Paypal comme solution pratique pour le paiement en ligne de vos frais d'abonnement. Paypal prend en charge un large éventail de méthodes de paiement (Visa, Mastercard, Amex, compte bancaire, etc) et ne nécessite pas que vous ayez déjà un compte avec eux. Si vous désirez procéder à un paiement par chèque de votre abonnement, merci de remplir le formulaire d'inscription et de l'envoyer au secrétaire exécutif de l'association (voir adresse ci-dessus). - Canadian Acoustical Association/Association Canadienne d'Acoustique c/o JASCO Applied Sciences 2305-4464 Markham Street Victoria, BC V8Z 7X8 - - - secretary@caa-aca.ca - Dr. Roberto Racca

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Acoustics Week in Canada 2020 Semaine canadienne de l'acoustique 2020



Online meeting

We are pleased to present you in this unusual September issue of Canadian Acoustics journal, the list of accepted abstracts for the upcoming 1-day celebration instead of AWC2020. As most of you know, because of the COVID-19 situation, the Acoustics Week in Canada (AWC) originally planned for October 2020 in Sherbrooke (QC) has been postponed in October 2021. Nevertheless, CAA Board of Directors, with Sherbrooke's organising committee, has decided to set up this 1-day celebration on October 9, 2020.

This online event represents a unique opportunity for students to present (live or preferably pre-recorded) their work in a Pecha-Kucha style, and have a chance to win one of the Best Student Presentation awards. As you can see from the preliminary program presenting here after (the final version will be available on the AWC website awc.caa-aca.ca), one main sessions will also be organized to cover the usual themes corresponding to each of the received abstracts. Others sessions include an "Acoustical Gems" luncheon (attractive educational resources, laboratory demonstrations or research results), one round-table session dedicated to the COVID-19 pandemic associated impacts, challenges and opportunities for the CAA community. The addition of the award ceremony, the annual general assembly and a recorded concert will make this a full day!

We sincerely hope that all members of CAA will seize that opportunity to regroup in 2020 despite the adversity of the current pandemic and we look forward to a successful and - in presence- event in Sherbrooke (Qc) in October 2021!

Olivier Robin, Conference Chair
Patrice Masson
Sebastian Ghinet

Conférence en ligne

Nous sommes heureux de vous présenter dans ce numéro de septembre de la revue Acoustique canadienne, la liste des résumés acceptés pour la prochaine célébration d'une journée, en lieu et place de l'AWC2020. Comme la plupart d'entre vous le savent, en raison de la situation COVID-19, la Semaine canadienne de l'acoustique (AWC) initialement prévue en octobre 2020 à Sherbrooke (QC) a été reportée en octobre 2021. Néanmoins, le conseil d'administration de l'ACA et le comité d'organisation de Sherbrooke, ont décidé de mettre en place cette célébration d'une journée le 9 octobre 2020.

Cet événement en ligne représente une occasion unique pour les étudiants de présenter (en direct ou de préférence pré-enregistré) leur travail dans un style Pecha-Kucha, et d'avoir une chance de gagner l'un des prix de la meilleure présentation étudiante. Comme vous pouvez le voir dans le programme préliminaire présenté ci-après (la version finale sera disponible sur le site web de l'AWC awc.caa-aca.ca) une session principale sera également organisée pour couvrir les thèmes habituels correspondant à chacun des résumés reçus. Les autres sessions comprennent un déjeuner "Acoustical Gems" (ressources pédagogiques attrayantes, démonstrations en laboratoire ou résultats de recherche), une table ronde consacrée aux impacts, défis et opportunités associés à la pandémie COVID-19, en ce qui concerne la communauté ACA. Finalement, une cérémonie de remise des prix, l'assemblée générale des membres ainsi qu'un concert enregistré clôtureront cette journée !

Nous espérons sincèrement que tous les membres de l'ACA saisiront cette occasion de se regrouper en 2020, malgré l'adversité de la pandémie actuelle. Nous espérons que l'événement qui se tiendra à Sherbrooke (Qc) en octobre 2021 sera couronné de succès et se déroulera en présence de tous !

Olivier Robin, Directeur de conférence
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Semaine canadienne de l'acoustique 2020

Acoustics Week in Canada 2020

Conférence en ligne - Online meeting

awc.caa-aca.ca/zoom

Programme préliminaire - Preliminary Program

Time	Activity
09:00-09:10	Mot de bienvenue – Welcome Note
09:10-10:00	Table ronde : Opportunités et défis de la COVID-19 dans le monde de l'acoustique - Round Table - COVID-19 Pandemic : impacts, challenges and opportunities for the CAA-ACA community
10:00-12:30	Sessions techniques – Main Session <ol style="list-style-type: none"> 1. Préservation de l'ouïe - Hearing Conservation 2. Acoustique musicale / Électroacoustique - Musical Acoustics / Electroacoustics 3. Traitement des signaux / Méthodes numériques - Signal Processing / Numerical Methods 4. Aéroacoustique - Aeroacoustics 5. Physio-acoustique - Physiological Acoustics 6. Acoustique sous-marine - Underwater Acoustics 7. Psycho-acoustique - Psychological Acoustics 8. Consultation - Consulting 9. Sciences de la parole - Speech Sciences 10. Acoustique architecturale - Architectural Acoustics 11. Chocs / Vibrations - Shocks / Vibrations 12. Sciences de l'audition - Hearing Sciences 13. Acoustique physique / Ultrasons - Physical Acoustics / Ultrasounds 14. Génie acoustique / Contrôle du bruit - Engineering Acoustics / Noise Control 15. Bio-acoustiques - Bio-Acoustics
12:30-13:20	Trésors acoustiques – Acoustical Gems
13:30-15:30	Présentations étudiantes Pecha-Kucha (session de 10 min de 20 diapos, 20 sec chaque, etc.) - Student Pecha-Kucha Presentations (10 min session for 20 slides, 20 sec each, etc.)
15:30-16:30	Assemblée Générale des membres - Annual General Assembly
16:30-17:00	Cérémonie de remise des prix - Award Ceremony
17:00-18:00	Concert - Concert



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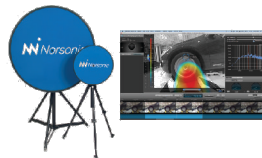
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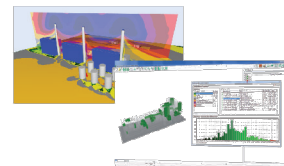
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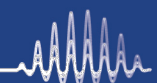
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1 - HEARING CONSERVATION - PRÉSERVATION DE L'OUÏE

In-Ear Audio And Speech Processing Algorithms For Digital Hearing Protectors

Farid Moshgelani, Jérémie Voix

Everyday more than one million Canadians working in noisy environments use Hearing Protection Devices (HPDs) to protect their hearing against the risk of noise-induced hearing loss (NIHL). Recently, a new type of digital HPD has been developed for the benefit of industrial workers exposed to noise. This digital HPD features three categories of specialized in-ear audio algorithms: The first is developed for in-ear speech capture under the HPD to enable the wearer's voice to be captured from inside the earcanal, while ambient sounds are played back at safe levels. The second deals with the classification of non-verbal events captured in the earcanal (e.g. coughing, swallowing, teeth or tongue clicking) to enable health monitoring applications for industrial workers. The third algorithm is dedicated to extracting biosignals from inside an occluded ear (e.g. heartbeat, breathing) to make it possible to track the activity and health of workers. In the current research program, the performance and functionality of the aforementioned specialized in-ear algorithms are optimized and validated across different processing conditions (e.g. different types and levels of ambient noise). Finally these algorithms are optimized for co-implementation and real-time processing into a single Digital Signal Processor (DSP). This presentation presents the required steps of the current work as well as the envisioned work for the development and qualification of a speech intelligibility framework dedicated to in-ear speech signals.

3 - SIGNAL PROCESSING / NUMERICAL METHODS - TRAITEMENT DES SIGNAUX / MÉTHODES NUMÉRIQUES

Acoustical Measurements Of The Roman Theatre Of Verona By Mapping The Sound Reflections In Real Time

Antonella Bevilacqua, Lamberto Tronchin, Francesca Merli, Marco Dolci, Umberto Berardi

Nowadays the auralization has been extensively performed inside enclosed spaces. This paper proposes the use of multi-channel spherical arrays applied to the Roman theatre of Verona. Both speaker and microphone have been used in order to achieve the graphical mapping of the sound reflections measured outdoor. Although the employed equipment is capable to change directionality and beamforming, in this experimentation the loudspeaker has been employed as an omnidirectional sound source, while the microphone continued to divide the impulse response (IR) in small frames by using the MIMO technique. By setting the equipment in this way, the energy associated to each virtual microphone can be computed and represented as a coloured map overlaid by a graphical interpolation. The new representation method shows clearly how the sound ray hits the boundary surfaces before reaching the receiver, over a full spectrum width, having a visible idea of how to identify the effectiveness of those surfaces generating early reflections or to be cause of unpleasant echoes

8 - CONSULTING - CONSULTATION

Noise From Outdoor Live Events In Downtown Montreal: Regulatory Framework, Complaints Management And Predictions Tools

Romain Dumoulin

The Quartier des spectacles, Montreal's major cultural district is a densely populated and rapidly developing sector that hosts numerous festivals and events throughout the year. These activities impact the neighborhood's soundscape and generate noise annoyance and complaints. In an effort to improve the proactivity of its noise management process, we assisted the City of Montreal in conducting a diagnosis of the current situation and provided recommendations on the regulatory framework and the use of environmental noise monitoring and prediction tools. Based on the analysis of complaints data and meetings with the main stakeholders (event promoters, sound engineers, noise control technicians, city officials from the Festival & Events department), we evaluated the complaints management process, the current regulatory framework and the strategy and resources put in place to ensure its application. We noted a sharp contrast between the management process and the information and guidelines presented in official City documentation. Spatial patterns in the locations of the noise complaints were identified and analysed. The noise level limits and its assessment methodology were identified as the main limitations. Our recommendations regarding the design and update of both the regulatory framework and the complaints management are presented. Our recommendations on the use of noise prediction tools are expanded under the following areas: 1. decision-support for city officials and event promoters, 2. Noise policies design for the development of location-specific noise limits, 3. Content creation for communications and outreach purposes.

9 - SPEECH SCIENCES - SCIENCES DE LA PAROLE

Investigation Of Motor Equivalence And Tongue Muscle Excitation Patterns In Simulated English Vowels

Noor Hisham Al-Zanoon, Daniel Aalto

Motor equivalence is a motor system's ability to achieve the same end target with varying input from individual components of that system. In speech, a particular tongue configuration can be produced by many different muscle excitation patterns. Previous studies have used various experimental techniques (imaging and kinematics tracking) to estimate the variability of muscle excitation patterns. However, these studies are limited in understanding to the surface of the tongue and cannot directly observe biomechanical parameters such as muscle activation patterns, and individual muscle contributions. Computational models of the tongue have the potential to measure muscle activation patterns. In the current study, motor equivalence is systematically studied by simulating the motion of tongue between a neutral position and two English vowels (/i, æ/). ArtiSynth is an open-source simulation platform that uniquely supports the combination of multibody and finite element (FEM) models. ArtiSynth provides a generic jaw-tongue model that fully couples the jaw with an FEM tongue. Target muscle excitations for each vowel trajectory are estimated using inverse simulation methods. For each tongue muscle contributing to the trajectory, its relative weight (contribution) will be varied from using probabilistic sampling methods, while keeping other contributing muscles at a constant weight. The excitation patterns have a high dimensionality and are reduced using principal component analysis and clustered. The excitation patterns are compared using correlation index to quantify the similarity of the muscle excitation patterns. By understanding of variation in muscle excitation patterns, further insight into compensatory strategies, individual muscle contributions will be gained.

Socio-Phonetic Tendencies And Linguistic Aspects Of English Contemporary Commercial Music (Ccm)

Gianmarco Perna

The aim of this research is to set up a consistent theoretical arrangement concerning the socio-linguistic and socio-phonetic aspects of contemporary commercial music (CCM), which appears to be more and more unevenly and manifold taking into account the previous research by Trudgill (1997), Simpson (1999) and others. The massive use of phonetic variation and style switching in contemporary western singing style is analyzed mainly focusing on its phonetic, cognitive and semantical relevance. Some examples of metric, socio-linguistic and stylistic variation are provided afterwards, so that a global diagram of linguistic habits might be traced. Other collateral aspects are recollected, mostly concerning the effects of CCM experience on L2 users.



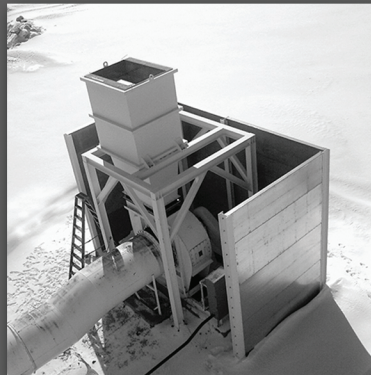
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10 - ARCHITECTURAL ACOUSTICS - ACOUSTIQUE ARCHITECTURALE

Variance Of Reverberation Time, Clarity, And Speech Transmission Index In Gymnasium

Greer Stanier, Umberto Berardi

No federal standards that specify the acoustical quality of gymnasiums exist despite the persistent issue of poor speech intelligibility in these spaces. The only provincial standard to do so is the Alberta Infrastructure and Transportation; Standards and Guidelines for School Facilities, which specifies a maximum reverberation time for gymnasiums. Reverberation time is the common metric but it is not the best indicator of speech intelligibility in these educational spaces. Clarity and Speech Transmission Index are more closely correlated to clear speech and are used in other standards to ensure a good environment for instruction in rooms with high background noise. The aim of this work is to characterize four gyms using these three parameters to analyse whether they are good metrics to quantify the acoustic quality of this typology. The analysis involved collecting results from field testing the gymnasiums at two heights and subsequently modelling them in ODEON for comparison. It was shown that when measured in the field under ISO 3382, the clarity has too much experimental deviation, while STI was consistent between both the measured and the modelled data.

The Roman Theatre Of Verona: A Different Representation Method Of The Acoustical Parameters.

Antonella Bevilacqua, Lamberto Tronchin, Francesca Merli, Marco Dolci

Although many parts of the Roman theatre of Verona have been lost for ever, the reconstruction of the cavea at its original shape, after the demolitions of heterogeneous buildings invading improperly the site throughout the centuries, gives the possibility to evaluate the acoustics of this unique place. A specific study was carried out by using a particular software, enabling to predict the room-acoustical characteristics of the theatre. Both monoaural and binaural measurements were undertaken on site, highlighting how the sitting areas can have a good or lack of listening. Whilst many acoustical investigations have already been completed during the 20th century in order to set in function the Roman theatre of Verona with summer shows' programs, the results of this study contribute to refine the acoustical parameters based on a different representation method.

Analysis Of Environmental Sound Levels In Italy During The Covid-19 Emergency

Jacopo Fogola, Giovanni Brambilla, Antonino Di Bella, Gaetano Licitra, Rosalba Silvaggio, Eleonora Carletti

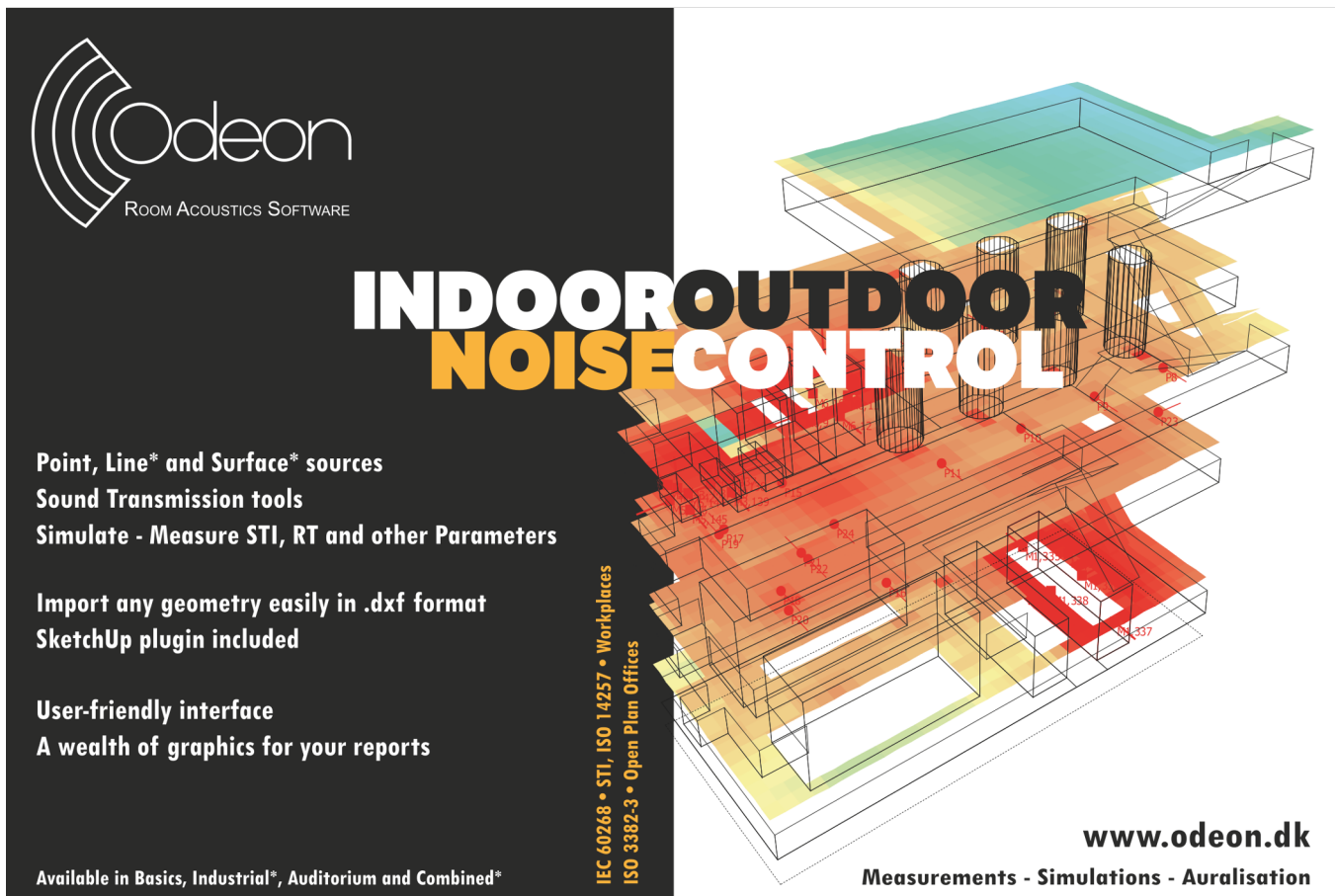
The emergency due to COVID-19 outbreak has led to unique and, perhaps, unrepeatably acoustic scenarios. The closure of schools and break of non-essential economic activities, the widespread use of smart working and the general requirement to stay at home have caused a significant decrease of people mobility and outdoor human life, with a consequent significant variation in noise levels and soundscapes, especially in urban areas. In order to investigate the impact of such restrictive measures in the acoustic climate, a joint research project has been signed between the Acoustical Society of Italy (AIA) and the Italian National System for Environmental Protection (SNPA). The main objectives of the project are: - to collect and organize, through a geographical information system, the data measured by public bodies, companies, acoustic consultants and private citizens; - to perform a large-scale first level analysis on sound level variations by different type of sources; - to carry out an in-depth study in some sample areas on specific acoustic effects, like variations on spectra, noise mapping, people exposure, traffic flows, number of people gathering in "movida" areas, ambulances siren impact, etc.; - to acquire information and knowledge useful for the study of quiet zones. This paper will present the general context of the initiative, a summary of the available information and data and the analysis methods applied so far.

The Effect Of Sound Masking On Employees' Acoustic Comfort In Open-Plan Offices

Joonhee Lee, Roderick Mackenzie, Vincent Le Men, François Gariépy, Farideh Zarei

As the ambient sound level self-generated by occupants in an office varies according to the occupancy rates and activity types, ambient sound levels alone cannot be relied upon to provide effective speech privacy and freedom from distraction. Sound masking systems are commonly employed in open-plan offices to achieve a controlled minimum level of background sound. The loudspeakers emit a neutral sound spectrum similar to a ventilation

system so as to decrease the signal-to-noise ratio of unwanted incoming speech, making it less intelligible and thus less distracting. Many previous studies have investigated the optimal level and spectrum of the masking sound in open-plan offices, but most studies have conducted subjective testing in a laboratory setting instead of actual office environments. Thus, this study aims to examine the relationship between perceived speech privacy of employees and sound masking configurations in two operational open-plan offices located in Quebec. The testing was carried out over six weeks, with varying overall sound levels of the sound masking systems. The employees were asked to fill out subjective questionnaires before and after each change in conditions about how the sound environment impacted their comfort and work performance during the study. The statistical results show that the masking sound conditions are significantly more satisfactory than the sound condition without the masking sound. The results can help to understand the optimal sound masking system condition in open-plan offices, but also serve to demonstrate the importance of maintaining controlled minimum background sound levels in office environments.



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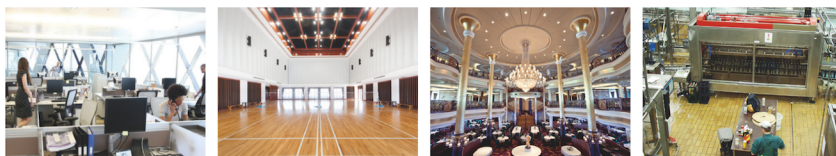
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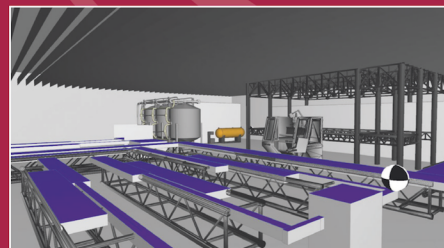
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THE EVOLUTION OF THE ACOUSTICS OF A MEDIEVAL CHURCH

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1 Introduction

Churches are acoustically complex spaces due to both their large dimensions as well as the acoustically reflective materials used. Over time, the long reverberation times of churches have allowed for the development of sacred music; in fact, the sound tail inside the churches improves the listening to organ music as well as songs, increasing the participation of the faithful in religious functions. In recent decades, churches have been used both for classical and symphonic music concerts as well as conferences and conventions, but the results have not always been positive since the acoustic properties of the churches are different from those of theatres [1]. Furthermore, the Second Vatican Council amended the Catholic liturgy, giving more importance to the verbal communication, although this requirement was not supported by the passive acoustics of the churches with long reverberation times and reduced speech intelligibility [2]. In the years, in order to improve listening conditions, electroacoustic systems are often placed inside churches. However, speech intelligibility can be improved by means of an acoustic correction of the spaces through the reduction of the reverberation by inserting appropriate sound-absorbing materials.

Traditional porous sound-absorbing materials with a suitable thickness, absorb sound energy at medium and high frequencies and are successful for acoustic corrections [3, 4]. However, monumental churches have various problems due to both the presence of low frequencies components of the sound tail as well as the difficulty of using traditional materials for historical and architectural needs: the walls cannot be covered with traditional materials. Therefore, there is a need to experiment innovative solutions for the acoustic correction of the rooms, such as transparent micro-perforated sheets for medium and high frequencies and acoustic resonators for low frequencies. Acoustic resonators can be obtained by perforating ceramic tiles and installing them at an appropriate distance from the rigid wall in order to obtain an adequate sound absorption at low frequencies. This paper is dedicated to the investigation of the acoustic characteristics of the cathedral of Carinola, in Italy which was subject to a restoration for improving its acoustics.

2 Acoustic measurements

The church has a volume of 7.500 m³ and an internal plant surface of 5.000 m². The church has a central large nave and

three lateral smaller naves, following a typical Medieval plan. The acoustic measurements were carried out with an omnidirectional sound source located on the altar and 12 microphone points of measurement placed in different positions in an area occupied to the listeners, in accordance with ISO 3382 [5]. The sound source was powered with a MLS signal. During the acoustic measurements the background noise was lower than 35 dBA, the church was empty and the furniture were hard chairs. Figure 1 shows the plan of the church with the indication of the position of the source and of the receiver microphone points. The sound source was placed at a height of 1.6 m from the floor and the microphone at a height of 1.3 m, in an area occupied to the listeners. The monaural acoustic parameters analysed are EDT, T30, C80, and D50. Table 1 shows the average values of the acoustic parameters in the octave band from 125 Hz to 4 kHz. The values of EDT and T30 exceed on average the 4 seconds, the average values of C80 = -5 dB, while the average values of D50 = 0.25. The average value of the parameter STI = 0.33. The church does not meet the criteria of good listening for the music and the speech [2, 5].

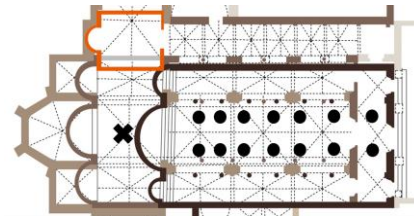


Figure 1: Plan of the church with the indication of the position of the source and of the receivers.

Table 1: Average acoustic parameter measured.

Freq [Hz]	125	250	500	1000	2000	4000
EDT, s	4.8	4.5	4.0	3.7	3.1	2.5
RT, s	4.7	4.6	4.0	3.6	3.0	2.5
C80, dB	-5.1	-6.3	-5.5	-3.9	-3.3	-2.4
D50	0.2	0.1	0.2	0.2	0.2	0.3

Figure 2 shows the reverberation time parameter trend, with distance sound source-receiver at the frequency of 1000 Hz. The parameter does not change with the distance sound source-receiver, proving that the acoustic field is diffuse.

In the late 1960s, Shankland published studies on more than Roman and Medieval churches discussing their acoustic qualities. In all the environments considered the sound was judged to be very widespread and without audible echo due to the richness of the architectural and sculptural details. Figure 3 shows the trend of the reverberation time measured in the considered church compared to others [6].

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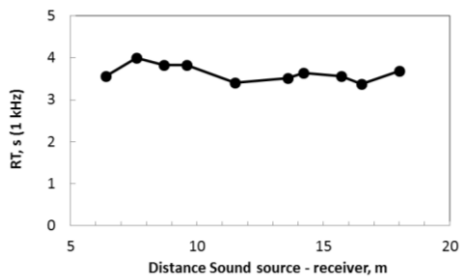


Figure 2: Reverberation time parameter, with distance sound source receiver at the frequency of 1000 Hz.

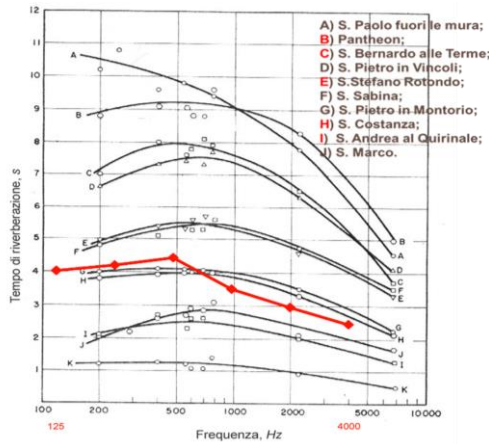


Figure 3: Comparison of reverberation times measured in different churches and in the present case study (in red).

3 Acoustic correction and discussion

The results showed in the previous section show that the church has inadequate acoustic characteristics for a good speech intelligibility, and requires intervention to fully adhere to the suggestions of the Second Vatican Council. The CAD model, shown in Figure 4, was imported into “Odeon” Room Acoustics Software. The sound source is placed on the altar and the receivers among the seats of the audience. The first step, the acoustic model calibration, consisted of setting the absorbent coefficient values for all the virtual model surfaces and the scattering coefficient ones. The procedure was stopped when, for each octave band frequency from 125 Hz to 4.0 kHz, the calculated reverberation time value (T30) was within $\pm 5\%$ of the measured one. Table 2 shows the values of absorbent coefficient used in the modeling.

A practical problem for medieval churches that traditional sound-absorbing materials such as polyester cannot be used for acoustic corrections for artistic conservation needs. A possible solution was hence to cover the side walls of the church with sound-absorbing plaster. This solution is not invasive and allows the preservation of the church from a monumental point of view. Table 2 report the sound absorbing values of the sound-absorbing plaster selected.

Figures 5 show the spatial average distribution of RT and EDT at 1000 Hz modelled with the plaster intervention. These figures show the reduction of these acoustic parameters and the clear improvement of the relative listening quality within this church.

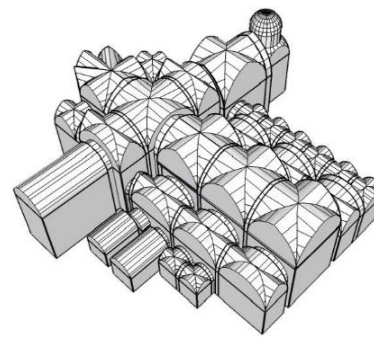


Figure 4: 3D model of the church used to test possible interventions for its acoustic correction.

Table 2: Values of absorbent coefficient of used in modelling.

Freq, Hz	125	250	500	1000	2000	4000
Plaster	0.03	0.04	0.04	0.05	0.06	0.08
Marble	0.11	0.12	0.13	0.14	0.15	0.16
New plaster	0.2	0.3	0.6	0.7	0.8	0.8

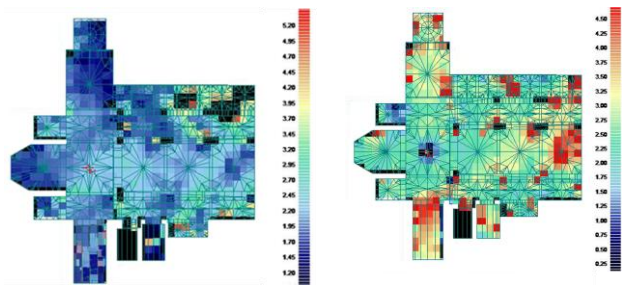


Figure 5: Distribution of the RT (left) and EDT (right), at 1000Hz.

4 Conclusion

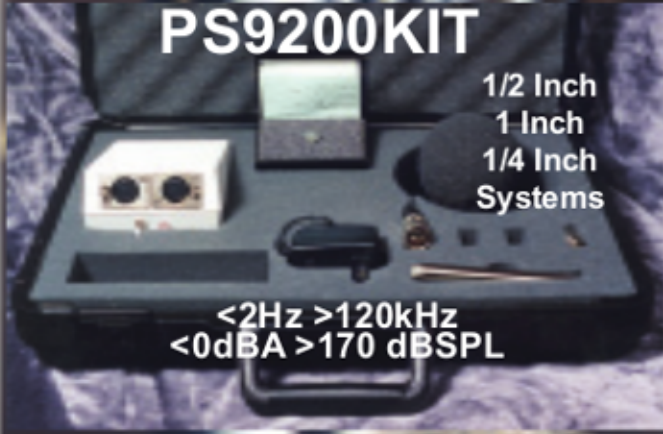
This paper presented the study of the intervention for the acoustic correction of the Medieval cathedral of Carinola in Italy. The intervention aimed to shortening the reverberation time by substituting the plaster with a sound absorbing plaster. Acoustic interventions showed the homogeneity of acoustic across the floor plan and the possibility to obtain a reverberation adequate for an easier speech perception.

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A Critical Review On Controlling The Supercooling Of Water Through Ultrasound

Amrit Kumar Thakur

Supercooling is highly undesirable phenomenon and consumes huge amount of energy for energy storage application and thus, finding methods to reduce the degree of super-cooling of water is fundamental to advance the thermal energy storage technology. Different methods are being adopted to mitigate the supercooling using Nanoparticles, fins and metal metrics. However they are not good with increasing number of cycles and also increase the system weight. With the tremendous development in acoustic, utilisation of ultrasound , leads to significant reduction in supercooling degree and huge energy can be saved using the ultrasound application in solidification of water. This paper will discuss the extensive research work carried out in the field of reduction in the supercooling degree with usage of ultrasound and present the key findings for the future work. This review will give a new dimension in using ultrasound for energy saving potential for thermal energy storage application.

14 - ENGINEERING ACOUSTICS / NOISE CONTROL - GÉNIE ACOUSTIQUE / CONTRÔLE DU BRUIT

Design And Experimental Validation By 3d Printing Of A Permeable Silencer Metamaterial

Francesco Bianco, Francesco Brocchi, Umberto Berardi, Gaetano Licitra

The use of acoustical metamaterials (AMMs) can answer several issues in architectural and building acoustics, especially problems related to low-frequency noise control. This paper reports the investigation of an acoustic metamaterial permeable to air. This analysis and design of an AMM, conceived to improve the sound attenuation in the range of middle-low frequencies, using subwavelength structures are reported. A Finite Element Method (FEM) investigation allows us to analyze and optimize the acoustic performance of the AMM. A parametric design leads to tuning the operating frequencies behavior of the AMM. The AMM device is then experimentally validated by 3d printing the prototype and testing it. A comparison between the estimated and measured results is finally reported. This study confirms that the AMM effectively acts as a permeable and highly effective and selective sound silencer, which could be used in wide range of applications, such as building technology to provide natural ventilation to indoor environments, or directly integrated in ducts, for fans noise reduction.

Development Of A Mobile Full Face Tracking System During Speech Production

Andrew(U San) Chao, Roujan Khaledan, Kieran Armstrong, Daniel Aalto

Motion tracking systems, such as Optotrak, are used for capturing facial movements (facial gestures, jaw, and lip motions). However, the standard tracking systems are expensive and have limited availability. We propose a mobile device app capable of capturing facial movements with high speed video and audio recordings while a participant reads target sentences from a mobile device screen. The app is created in Xcode and is available on TrueDepth camera iOS devices. The app uses ARKit, Apple's Augmented Reality platform, and the iPhone's front facing TrueDepth camera. The app fits a mesh of 1220 points to the face at a rate of 60 frames per second (fps) based on built-in infrared surface scanning technology. Simultaneously, video (60 fps) and audio (44.1kHz) are recorded with Apple's ReplayKit. The speech task, the speaker's face with the fitted surface mesh, control buttons, and the distance to the camera are displayed in the user interface. After recording, the acquired data is transferred to a comma separated file with a Python script. The developed pilot mobile app for full face tracking offers an accessible alternative for traditional motion tracking systems creating opportunities to remotely collect articulatory data for research and clinical purposes.

MINI-WIND TURBINE NOISE MEASURED INSIDE NEAR-BY HOUSES

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1 Introduction

The possibility of using the wind to rotate blades and to obtain the lifting of the water or to operate millstones is an ancient technique. Today, wind power keeps being fundamental to the increased importance of renewable energy. In Italy, the country of the present study, there were 81 wind farms installed in 2001, with a total capacity of 664 MW; in 2015, there were 2,734 wind farms with a capacity of 9,162 MW. The environmental impacts caused by the construction of wind farms include the occupation of the territory, visual impact, acoustic emissions, electromagnetic emissions, possible interference with flora and fauna, and discomfort for the populations living near the wind farms. In particular, one of the main complaints reported by the resident population is the noise generated by the rotation of the wind turbine blades [1]. The functioning of a wind tower generates the aerodynamic noise produced by the rotating blades and the mechanical noise inside the nacelle. The noise generated by the operation of the wind towers, with the same perceived sound level, is more annoying than other anthropic noises. Although the sound levels caused are modest in the order of 30-50 dBA, this type of noise, due to the particular tonal component, is highly annoying. Usually, the noise emitted by a wind turbine is a broadband noise concentrated in the frequency range 300 Hz – 2000 Hz [2,3]. In this paper, the acoustic measurements inside a house of the noise produced by the operation of a 200 kW wind turbine are reported.

2 Methodology

The house in which the acoustic measurements were carried out is located in a small rural municipality. The area is a plateau within a large basin at about 700 meters above sea level, located in the central area in the South Italian Apennines. The height of the gearbox is 30 m, the rotor diameter is 20 m, and the blades rotation speed is 20 – 60 rpm. Blades began to move with wind speed around 3 m/s; and the rotation is stopped for safety conditions when wind speed is 25 m/s. The highest power production starts for wind speeds over 15 m/s. The tower is located to the east of the house, and the land is flat and has modest vegetation. The distance between the home and the tower is 250 m. During the measurements, the window was open to assess the maximum disturbance.

The acoustic measurements were carried out using a sound level meter model Larson Davis LXT1, which was calibrated with a Larson Davis CAL 200. The instruments were compiled with the requirements of the IEC 61672-1 standard "Class 1". The sound level meter was configured to acquire the sound equivalent level of the "A" weighted and the L95 statistical level; this parameter is defined as the level exceeded for 95% of the observation time. The "A" -weighted filter (dBA) was used because the annoyance response to due to wind turbine noise, is related to "A"-weighted levels.

The following regulatory approaches were adopted to evaluate the annoyance produced by the wind turbines [4,5]:

- Differential criterion: the differential noise level is represented by the difference between the ambient noise level and the residual noise level. If the difference between the level of environmental noise and the residual level (wind turbines turned off) is less than 5 dBA daytime and 3 dBA nighttime, then the noise generation is considered acceptable.

- Normal tolerability criterion: the background noise (L95) is measured when wind turbines are stopped, and the equivalent level is evaluated. The normal tolerability limit is 3 dB.

3 Sound propagation theoretical models

One of the problems encountered during the installation of a wind tower is the theoretical evaluation of the noise introduced into the living environment. This evaluation is necessary to establish if the installation of the wind tower will cause annoyance to the people living in the chosen area. The most used model is based on ISO 9613-2 [4]. It considers the sound source as a point, although a wind turbine is a complex system that can be considered a point sound source only when there is a considerable distance between the sound source and the receiver. For the determination of the noise levels inside a receiver point, the standard ISO 9613-2 provides a theoretical method to evaluate the sound attenuation, with the source - receiver distance, in outdoor propagation. The standard calculates the equivalent sound pressure level assuming meteorological conditions that favor sound propagation, by applying the following relationship:

$$L_p = L_w + DI\theta - A_{div} - A_{atm} - A_{gr} - A_{bar} - A_{misc}$$

where L_p : sound pressure level (dBA); L_w : sound power level (dBA); $DI\theta$: directivity; A_{div} : attenuation due geometric divergence; A_{atm} : attenuation due to atmospheric absorption; A_{gr} : attenuation due to ground effect; A_{bar} : attenuation due to a barrier; A_{misc} : attenuation due to foliage or industrial sites.

The application of the calculation model of noise propagation appears to be precautionary as it provides an overestimation of the levels when considering only the attenuation of the noise caused by the geometric divergence, not consid-

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ring the other attenuating factors such as atmospheric absorption, as well as the presence of obstacles and vegetation. Numerical simulations based on engineering approaches are, in many cases, a rapid application. In a simplified way, the sound pressure level is given by the formula: $L_p = L_w - A_{div}$ with $A_{div} = 20 \log(D) + 11$, where D is the distance between the sound source and the receiver and A_{div} is the sound attenuation which occurs during propagation. For a wind tower of nominal power of 200 kW, L_w is 100 Dba; so, the theoretical sound pressure levels is $L_p = L_w - A_{div} = 41$ dBA.

With the ISO 9613, it is possible to evaluate the sound pressure level at the receiving point located in a home. For the evaluation it is necessary to estimate the effect of the attenuation of the open window or the value of the difference between the sound level measured externally and the level measured internally in the home. This value is estimated to be around 4 or 5 dBA [3]. The sound level inside the house is equal to the sound level estimated in the receiving point subtracted from the attenuation value of the open window. A theoretical level inside a home of 37 dBA was predicted.

4 Acoustic measurements and discussion

The acoustic measurements were made by placing the sound level meter at about 1.6 m from the floor, and 1.0 m from the balcony in the first-floor room used as a bedroom. Measurements were performed with windows open in the maximum disturbance condition. Several sessions of measurements were performed corresponding to two operating conditions of the wind turbine. Figure 1 shows a typical measurement session with the time history of the measured sound pressure level. The environmental noise when the source is turned on, the residual noise when the source is turned off, the background noise L95 when the source turned is off and the wind speed are shown in Table 1.

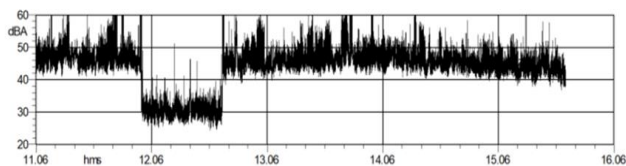


Figure 1: Time history of the sound pressure level.

When the wind turbine is off, the residual noise level, measured inside the home, is equal to 30 dBA, while when the wind turbine is on, the measured sound pressure level is equal to 45-50 dBA. A neglected aspect regarding the emission of noise by small wind turbines with a cylindrical tower is that the noise emitted is not only due to the rotation of the blades. The noise emission is a complex phenomenon, also emitted by the entire tubular structure of the tower put into vibration by the rotation of the blades. The theoretical simulation model therefore underestimates the noise level inside home. Near the wind turbine the following problems were observed: the blade rotation speed is about 30 rpm; the rotation of the blades is discontinuous, it depends from the instantaneous wind speed, and this generates an intermittent noise. Intermittent rotation with a speed of about 30 rpm can cause damage to the blade elements. Finally, it was considered

the theoretical relationship for the evaluation of the noise introduced in the home due to the functioning of a tower, applying the ISO 9613 standard. In the hypothesis of point-sound source, it was found that the theoretical relationship gives a value of the sound pressure level of $L_p = 37$ dBA. Therefore it underestimates the measured value of the sound pressure inside the house. From the comparison, a difference of 13 dBA between measured and calculated values was obtained.

Table 1. Acoustic measurement results.

Time of the day	Environmental noise dBA	Residual noise dBA	Background noise L95 dBA	Average wind speed m/s
19:00 – 22:00	42.4			8
06:20 – 09:00	44.0			9
16:00 – 17:30	46.1			10
18:00 – 22:00	40			8
22:00 – 06:00	40			8
06:00 – 9:30	44.8			8
23:00 – 04:30		30.0	21.3	9
06:00 – 13:00	50.2			15
22:45 – 01:00	40			10
01:30 – 04:30		31.0	20.7	10
01:00 – 03:30	41.0			8
03:40 – 04:10		31.5	27.6	8
21:40 – 22:00	39.0			9
01:40 – 04:40		30.5	24.0	8
06:00 – 10:00	47.6			12
11:10 – 12:00	49.4			13
12:00 – 12:30		31	28	10
12:30 – 15:45	47.0			12
14:00 – 20:00	46.7			12
11:15 – 15:15	46.6			11
19:45 – 22:00	43.7			12
22:00 - 23:45	37.0			5
19:45 – 22:00	43.3			11
22:30 – 01:00	41.2			9
00:00 – 04:30	40.0			9
06:00 – 16:00	44.0			12

5 Conclusions

In this study, we report the acoustic measurements of the noise produced by the operation of a wind turbine with a nominal power equal to 200 kW performed inside a house. In the house, the wind tower increases the sound level of about 10 dBA. The theoretical model for the evaluation of the noise introduced in a house due to the functioning of a tower underestimates the measured value of the sound pressure level.

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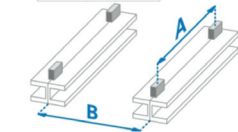
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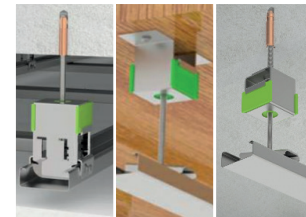
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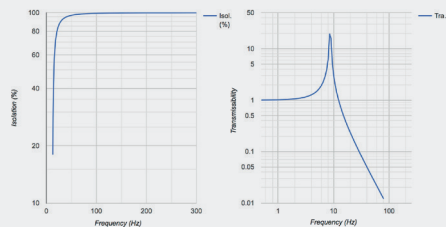
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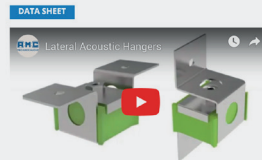
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Load (%)	66.52 %
Defl. (in)	0.15
Nat. Freq. (Hz)	8.73 Hz

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



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“listen To Your Heart”: Exploring The Link Between In-Ear Audio And Emotions

Danielle Benesch, Corentin Delain, Rachel Bouserhal, Stefanie Blain-Moraes, Jérémie Voix

Wearing passive hearing protection to manage auditory sensitivities can sometimes lead to the opposite end of the spectrum where the surrounding sounds are over-attenuated and wearers can no longer fully engage with their surroundings. A “smart” hearing protection device could satisfy both needs by attenuating distressing sounds while relaying useful sounds. And since each individual may be sensitive to a unique constellation of sounds, this device would ideally be customized to the needs of each wearer. A hearing protection device could conceivably adapt to the idiosyncratic sensitivities of individual wearers by monitoring their biosignals to detect sound-induced distress. When the ear canal is acoustically sealed by a hearing protector, biosignals can be captured due to bone-conduction sound amplification or the “occlusion effect”. The amplified biosignal sounds can be recorded with an in-ear microphone and classified automatically. Among the audio events that can be extracted from in-ear microphone data are heartbeat signals. Drawing upon previous psychophysiological research using heart rate and heart rate variability to study emotions, this project proposes inferring an individual’s affective state based on the heartbeat extracted from in-ear audio. To assess the suitability of the in-ear heartbeat as an indicator of affective state, stimuli intended to evoke certain emotions are played while audio is recorded inside the ear. Preliminary results are discussed, as well as the feasibility of a potential application: the automatic classification of distressing sounds by a hearing protection device.

In-Ear Speech Capture On Electronic Hearing Protectors: Optimization Of The Denoising Algorithm In Transparent Mode

Corentin Delain, Farid Moshgelani, Rachel E. Bouserhal, Jérémie Voix

Providing industrial workers with satisfactory hearing protection and communication in noisy environments is still a challenge and often requires a compromise of one or the other. An intra-aural hearing protection device (HPD) equipped with an in-ear microphone (IEM), miniature loudspeaker, and an outer ear microphone (OEM) has been recently developed for communication in noise. The voice of the wearer is captured from inside the occluded ear canal and the speech signal is further denoised from residual ambient noise and subsequently enhanced to increase its frequency bandwidth. Currently, when the ambient noise level is greater than 85 dBA, the denoising of the IEM signal is performed in a so-called “noise isolation mode”, where the HPD provides full passive attenuation of ambient noise. However, in moderate ambient noise levels, it is desirable to maintain the situational awareness of the wearer by allowing ambient sounds captured by the OEM to be played through the internal loudspeaker (electronic “talk through”). This mode of operation is herein referred to as “acoustical transparency mode” and creates added challenges, as the IEM picks up the voice of the wearer as well as the ambient noise played back by the loudspeaker inside the occluded ear canal. The present study details the denoising approach developed around the use of adaptive filters. The effects of loudspeaker gain, ambient noise level, and fit of the HPD on the transparency mode algorithm are investigated to optimize its performance and integration.

Hpd Fit-Testing Feature Developed Within A Hearing-Care Platform For Musicians

Lucas Einig, Romain Dumoulin, Isabelle Cossette, Jérémie Voix

The hearing-care platform is a dedicated software and hardware solution intended for university music students to assess an individual’s noise exposure and to promote hearing health. As the level of exposure is measured using a calibrated microphone set on a smartphone app, the attenuation provided by the -possible- use of a hearing protection device (HPD) needs to be taken into account in the calculation of the protected noise exposure. To quickly estimate the attenuation provided by a HPD, a new app functionality has been developed featuring a) an audio stimulus generator – that can produce loud tones through the smartphone embedded loudspeakers, b) a graphical user interface that can display a count of the audio stimuli perceived, and c) an attenuation prediction algorithm that can estimate the overall attenuation of the HPD under test. The proposed measurement approach relies on a threshold-based method where sequences of octave band-centered narrowband stimuli are played in

steps of 5 dB. The user simply counts the number of tonal bursts perceived before stimuli become inaudible in two conditions: when both ears are occluded with the HPD and when they are not occluded. From the two count values, the HPD octave-band attenuation is computed. Attenuation data can be assessed for different HPDs and applied to each activity exposure with an adjustable wearing time (from no HPD to HPD being worn during the entire activity). In addition to improving individualized assessment, this feature is also a great educational tool to demonstrate the benefits of HPDs.

Evaluating The Accuracy Of Lip Motion Tracking Using Surface Scanning Face Tracking Technology

Roujan Khaledan, Andrew (U San) Chao, Caroline Jeffery, Gabriela Constantinescu, Daniel Aalto

Speech-Language Pathologists diagnose Motor Speech Disorders (MSD) by visually inspecting differences in facial motion, specifically range of motion and trajectory of the lips. Visual inspections are subjective, making it difficult to precisely track movement. Digitally tracking facial motion has the potential to refine the diagnostic process, characterize MSD, and monitor treatment impact. In contrast to traditional motion tracking systems, which are only available in specialized centers, mobile devices and the integrated facial tracking systems are ubiquitous and offer an accessible alternative to traditional systems. The goal of the present work is to evaluate the accuracy of lip tracking based on mobile surface scanning technology. Using a custom app based on Apple's augmented reality environment (ARKit), one of the authors recorded their facial movement for both natural speech and extreme non-speech gestures. This app tracks 1220 mesh points on the face while recording video (both at 60 frames per second). The TrueDepth iPhone camera was placed 55 cm from the speaker and positioned at their eye level. Accuracy was defined as the distance between a visible anatomical landmark on the lip (flesh point) and the corresponding tracked mesh point. For each gesture, the deviation of the flesh point from the mesh point was calculated from a single frame. Understanding the accuracy of the app for different tasks can have an impact on future clinical and research use, and it may motivate the development of an automated adjustment for the flesh point-mesh point deviation.

Direct Manipulation Of Variability In The Auditory Feedback System Via Real-Time Formant Perturbation

Daniel Nault

Auditory feedback is an essential part of speech motor control and speech learning. When feedback is perturbed in laboratory settings (e.g., Houde & Jourdan, 1998), speakers, on average, compensate for the perceived error. There is, however, considerable individual variability in the magnitude of speakers' responses to feedback manipulation (e.g., Purcell & Munhall, 2006). Here, we address one potential source of this variability by manipulating the predictability of auditory feedback of 20 female speakers using a real-time formant perturbation system. Participants produced the English word "head" 80 times in 3 different conditions. During the Perturbation phase of each condition (i.e., trials 20-50), subjects were presented with random first and second formant perturbations that produced feedback varying between the vowels in "hid" and "had". Predictability of the perturbations in the conditions varied, such that: (a) on each trial, a different perturbation was introduced, (b) perturbations were consistent for three trials, or (c) six trials. Time series analyses were performed to examine whether compensatory behavior differed among speakers in the three conditions of varying feedback predictability. Results will be discussed regarding the possible role of variability in speech motor control and the importance of developing methods to detect state-change in individual time-series data.

Transfer Of Training Across Speakers And Languages In Learning Time-Compressed Speech

Cynthia Sedlezky

A key criterion for successful learning is generalization beyond the training conditions. Here we examine the perceptual learning of time-compressed speech and study generalization to speech produced by different talkers in different languages. This research tests the importance of learning low-level acoustic properties of speech for transfer of training. Monolingual and bilingual adults were trained in English over 8 sessions using passages of progressively more time-compressed speech from a novel. The speech rate during training sessions corresponded to their threshold of intelligibility as assessed by scoring the SPIN sentences recorded at 14 rates (100-425%). To assess transfer of their ability, a similar task with English or French sentences produced in the same or a different

voice was tested at the end of the 8 sessions. Compared to a control group that underwent only baseline training (i.e. sentence rate fixed at 100%), both the monolingual and bilingual experimental groups achieved higher scores following training when tested on their ability to understand time-compressed speech in both English and in French. However, both voice and language changes produced reductions in performance. The results suggest that perceptual learning of time-compressed speech involves low-level acoustic cues that are independent of the language of training.



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A SURVEY OF FACTORS THAT IMPACT NOISE EXPOSURE AND ACOUSTICS COMFORT IN MULTI-UNIT RESIDENTIAL BUILDINGS

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Résumé

Les recherches sur l'exposition au bruit dans les immeubles résidentiels à logements multiples (IRLM) sont limitées, malgré les effets avérés du bruit sur la santé physique et psychologique des personnes. C'est ce qui motive l'étude actuelle qui vise à identifier les sources de bruit importantes dans les IRLM et à étudier les facteurs qui ont un impact sur le confort acoustique ainsi qu'à déterminer les différents impacts du bruit sur les occupants. Une enquête en ligne a été menée pour recueillir des évaluations subjectives de l'exposition au bruit et des effets du bruit auprès de 213 occupants. Les résultats d'une analyse de corrélation de Spearman montrent que, parmi les différentes sources de bruit extérieur, la gêne due au bruit de la circulation est celle qui présente la plus forte corrélation significative avec la gêne globale due au bruit extérieur (coefficient de corrélation = 0,64, $p = 0,000$). De même, la gêne causée par le bruit aérien à travers les planchers et les plafonds présente la plus forte corrélation avec la gêne causée par le bruit intérieur global (coefficient de corrélation = 0,47, $p = 0,000$). Les résultats montrent que l'âge du bâtiment, le niveau des étages, la proximité de constructions en cours, l'existence d'un balcon, le nombre de chambres, la proximité des ascenseurs et du vide-ordures sont des facteurs importants liés au bâtiment qui ont une incidence sur la gêne due au bruit. Les résultats montrent également que les facteurs personnels et démographiques, tels que l'âge des occupants, la durée de résidence, le statut de propriétaire, la relation avec les voisins et la volonté de payer pour de meilleures conditions acoustiques, ont une incidence significative sur les réponses subjectives. Même si les bruits intérieurs et extérieurs sont gênants, les bruits extérieurs, en particulier le bruit de la circulation, de la construction et des activités de voisinage, sont plus gênants et perturbent le sommeil que les sources de bruit intérieures.

Mots clefs : confort acoustique, bruit, nuisance, résidences à logements multiples

Abstract

There is limited research on noise exposure in multi-unit residential buildings (MURBs) despite the proven effects of noise on people's physical and psychological health. This motivates the current study which aims to identify important noise sources in MURBs and investigate factors that impact acoustic comfort as well as determine the various impacts of noise on occupants. An online survey was administered to collect subjective assessments of noise exposure and the effects of noise from 213 occupants. Results of a Spearman's correlation analyses show that, among the different outdoor noise sources, traffic noise annoyance has the strongest significant correlation with overall outdoor noise annoyance (correlation coefficient = 0.64, $p = 0.000$). Similarly, annoyance with airborne noise through floors/ceiling has the highest correlation with overall indoor noise annoyance (correlation coefficient = 0.47, $p = 0.000$). The findings show that building age, floor level, proximity to ongoing construction, existence of balcony, number of bedrooms, proximity to elevators and garbage chute are important building-related factors that impact noise annoyance. The results also show that personal and demographic factors, such as occupants' age, length of residency, ownership status, relationship with neighbors, and willingness to pay for better acoustic conditions, significantly affect subjective responses. Even though both indoor and outdoor noises cause annoyance, outdoor noises, especially noise from traffic, construction and neighborhood activities, cause more annoyance and sleep disturbance compared to indoor noise sources.

Keywords: acoustic comfort, noise, annoyance, multi-unit residences

1 Introduction

Residents of multi-unit residential buildings (MURBs) are usually located in dense urban environments and are exposed to high levels of noise from a variety of sources, including neighbors, construction and heavy traffic. Exposure to noise can have short term effects, such as annoyance and

disturbance of sleep, and long term effects including mental and physical health issues [1, 2]. Studies have shown that outdoor noise levels in cities around the world exceed the recommended 55 dB noise level for daytime and 45 to 50 dB for nighttime for minimum health effects [3, 4]. For instance, a study on environmental noise exposure in the City of Toronto measured daytime (64.1 ± 6.3 dBA) and nighttime (57.5 ± 7.8 dBA) noise levels at different locations around the city [5]. They estimated that 88.7% of the city's population is exposed to equivalent daytime outdoor noise levels above 55

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dB(A), which is the noise level limit set out by the World Health Organization (WHO) [6] for moderate annoyance, and 92.3% is exposed to nighttime outdoor noise levels above 45 dB(A), which is the noise level limit for sleep disturbance set out by WHO for a single noise event during the nighttime. Indoor noise sources, such as neighbors and building HVAC and service systems, can also be problematic in MURBs. Mitigating actions that occupants take to decrease their acoustic discomfort, such as keeping windows closed to block outdoor noise and turning their noisy HVAC system off, can cause poor indoor air quality and increase building energy consumption [7]. It is thus important to reduce exposure to both indoor and outdoor noise and improve the acoustic performance of MURBs.

1.1 Factors that impact acoustic comfort

Understanding factors that impact noise exposure and comfort is an important step in improving the acoustic performance of MURBs. A number of studies have thus investigated factors that impact acoustic comfort. Such factors can generally be divided into two groups: 1) noise-related and 2) human-related [8,9].

Noise-related factors include sound pressure level, frequency of noise, noise source, time and duration of noise exposure [8]. These noise-related factors depend on building and suite characteristics. The sound insulation level of walls, windows and floors is one of the main characteristics that impact the level and frequency of noise that is transmitted between suites or from outdoors [10]. For instance, heavyweight walls attenuate more low-frequency noise compared to lightweight walls [11]. While some studies report that occupants in buildings with heavyweight walls are more satisfied with the acoustical conditions compared to lightweight walls, other studies report no significant difference between acoustic satisfaction levels in the two types of buildings [10]. Similarly, the type and location of mechanical systems, such as HVAC systems, and the sound insulation levels of their components (e.g., ducts, fans and pumps) can affect exposure levels from noise produced by the system itself, as well as transmit and increase exposure to noise from outdoors or other suites [12]. The location of suites within a building is another factor that can impact noise exposure [13]. Suites facing highways, for example, are likely to have higher noise exposure levels [14]. Similarly, suites located on lower floors are exposed to higher levels of environmental noise, such as traffic and neighborhood activity noise, compared to those located on the upper floors [14].

Another noise-related factor that affects acoustic comfort is the source of noise. Occupants are likely to be exposed to both outdoor (e.g., traffic, construction, neighborhood) and indoor (e.g., airborne and structure-borne noise from neighboring suites, and HVAC noise). Most studies that evaluate how different noise sources affect occupants' responses, however, focus only on environmental/outdoor noise sources, typically road, rail and air traffic noise [9,15]. Elmenhorst et al. [16], for example, evaluated the effects of nighttime rail and aircraft noise exposure and found that respondents were more annoyed by aircraft noise than

railway noise. Similarly, a study that investigated the effects of eight outdoor noise sources found that respondents were more annoyed by traffic and aircraft noise than other noise sources such as trains and outdoor neighborhood noise [17]. Even though more focus has been given to outdoor noise sources, studies that include indoor noise sources that MURB occupants are likely to be exposed to found that indoor sources are more important than outdoor sources. In a laboratory study where subjects were exposed to the same A-weighted noise levels, Jeon et al. [18] found that occupants were more annoyed by people's conversation and drainage noise compared to traffic and floor impact noise. Similarly, Zalejska-Jonsson [19] found that airborne noise from neighboring suites has a stronger negative effect on acoustical satisfaction compared to outdoor noise. These results show that it is important to study the impacts of both outdoor and indoor noise sources when evaluating the acoustic performance of MURBs. In addition, the results also show us that the noise level alone does not determine acoustic comfort. The frequency component of the noise is as important as the sound energy level. Factors, such as expectation and duration of exposure, can also explain the differences between annoyance levels among the different noise sources [8, 9].

In addition to noise-related factors, studies show that acoustic comfort is impacted by human-related factors which include personal, societal and demographic factors [9]. Attitude towards the noise source is one important determinant of how occupants perceive and report on their acoustic environment [8, 9]. Having a positive attitude towards a noise source can result in a lower level of noise annoyance. Chan and Lam [20] found that people who use a new railway built near their residence expressed more tolerance of the noise source than those who did not use, thus did not benefit from the railway. Fear of danger from the noise source is another personal factor that can influence acoustic comfort [9]. Van den Berg et al. [21], for instance, observed a high correlation between worry due to aircraft and noise annoyance from aircraft, while the correlation between worry due to traffic and annoyance from it was lower. This can also explain why occupants report aircraft noise as the most annoying compared to other outdoor noise sources. Other factors, such as length of residency and homeownership status, are also found to affect acoustic comfort [9].

1.2 Measuring acoustic performance and the effects of noise

A method widely employed to evaluate the acoustic comfort in residential buildings is to measure the noise level either indoors or outdoors and compare values to those specified in national or international guidelines [4,5,22]. While this evaluation method is important to obtain an objective measure of noise levels in buildings, it is not sufficient to evaluate how and to what extent occupants are being affected by noise exposure as acoustic comfort depends on a person's perception of his or her acoustic environment [10]. Some studies have thus used other subjective and objective metrics

to evaluate the effects of noise exposure. Noise annoyance level is one metric that is used to capture the subjective nature of acoustic comfort which depends on noise sensitivity, attitude towards the noise source, the importance of the noise, predictability and other demographical, personal, societal and contextual aspects [23]. Sleep disturbance is another parameter used to evaluate the effects of noise exposure [9]. Field studies typically use surveys to evaluate subjective ratings of sleep quality while laboratory studies implement a more objective evaluation by using polysomnography and actigraphs to evaluate the effects of noise on sleep disturbance and overall sleep quality. While other evaluation methods, such as health effects, activity disturbance and effects on performance [3, 24, 25], have been included in studies assessing the effects of occupational noise exposure and general effects of noise on humans, evaluating such effects is not widely implemented for acoustic comfort studies in MURBs [26].

The current study aims to assess factors that impact noise exposure and acoustic comfort of occupants which are used as indicators of the acoustic performance levels of existing MURBs in dense, urban areas. The main objectives of this study included identifying the major sources of noise in MURBs, their effects on occupants and the importance of each noise source to overall acoustic comfort. We also sought out to identify building-related, and personal and demographic factors that impact noise exposure and acoustic comfort, as well as identify any noise mitigating strategies and behavioral adaptation to noise conditions. Identifying such factors will allow us to isolate the most important areas of work required to minimize the impacts of noise on occupants as well as reduce negative impacts on building energy consumption and other indoor environmental conditions.

2 Methods

An online survey (Table 6 in the Appendix) with 31 questions was implemented in SurveyMonkey. The survey first asks questions on 1) demographics, 2) relationship with neighbors, 3) respondents' weekday and weekend schedule (asleep, awake at home and away from home) and subjective evaluation of the time of day (morning, afternoon, evening and night) when noise is the highest, and 4) building information and suite type. It then asks participants to rate

their annoyance levels with different indoor and outdoor noise sources (listed in Table 1). The response scale ranged from "1= Not annoyed" to "5= Extremely annoyed". The survey also included questions on other effects of noise on occupants such as sleep and work disturbance, and noise mitigating strategies. In addition, the survey included open-ended questions so that respondents could report on additional factors that impacted their acoustic comfort which might not have been included in the closed-ended questions. This allowed us to identify additional noise sources and noise mitigation strategies. The survey also asked the street address of occupants' buildings, which allowed us to determine additional information about the buildings that were not covered by the survey as well as verify information provided by respondents, such as the age of the building and the total number of floors. We used a construction map of the city [27] to identify the proximity of buildings to ongoing construction during the period that the survey was administered. Only 200 responses were included in this classification as the rest of the respondents did not provide their building addresses. A building was considered to be close to ongoing construction if there was an ongoing construction within a 150 meters radius during the summer and fall of 2019 (July – October), which was when the survey was administered. In addition, we attempted to categorize buildings into those with small and large windows. A building and its suites are classified as having small windows if the window size is less than 50% of the wall area, and they are classified as having large windows if the window is more than 80% of the wall area. It should be noted that these classifications were based on visual inspections and no formal measurements of the window to wall ratios were taken. If we had doubts about whether a building fits in either category, it was left out of this classification. As such, only 187 responses were included for the window size analysis.

The survey was administered during summer and fall 2019 in the city of Toronto, Canada. To ensure that only residents of MURBs fill out the survey, we approached property managers of condominiums and apartments in the city of Toronto and asked them to distribute the online survey to all residents via email or posters that included a description of the survey along with a link to the survey and a barcode for easy access. Two-hundred and thirteen complete responses were collected from more than 30 buildings in

Table 1: A list of indoor and outdoor noise sources included in the survey questions.

Outdoor sources	Indoor sources		
	Systems and services	Neighbors	Other occupants
<ul style="list-style-type: none"> • Traffic • Construction • Outdoor neighborhood activities: restaurants, people on the streets, etc. • Weather (e.g., wind) 	<ul style="list-style-type: none"> • Water installations: plumbing, flushing toilet, shower, etc. • Heating/cooling: heaters, air conditioning, air supply grille, etc. • Service installations inside suite: laundry machine, kitchen fan, etc. • Service installations outside suite: elevator, garbage chute, etc. 	<ul style="list-style-type: none"> • Noise through walls: people talking, pets, etc. • Footsteps, moving furniture and other impact noise • Noise through floors/ceilings: people talking, pets, etc. • Noise from balconies • Noise from shared spaces: e.g., hallways and stairways 	<ul style="list-style-type: none"> • Other occupants in the same suite: talking, other activities

Toronto. Approximately 83% of the responses came from six buildings with total number of storeys ranging from five to 40 storeys.

A descriptive analysis of noise sources, annoyance levels, time of day when noise is highest, effects of noise on occupants and mitigation measures were presented first. Spearman's rank-order correlation analysis was used to test associations of annoyance with individual noise sources with overall acoustic annoyance in order to determine the most important noise sources that impact overall acoustic comfort. Spearman's correlation was also used to identify relationships between annoyance levels and floor level. Non-parametric tests, namely, Wilcoxon rank-sum test and Kruskal-Wallis test were used to determine whether there are statistical differences in annoyance levels among groups of suites with different characteristics, as well as among groups of respondents with different demographic and personal characteristics. Post-hoc tests (Dunn's test) were performed for significant Kruskal-Wallis test results. The analyses were conducted using R software version 3.6.1, and p-values less than 0.05 are considered significant.

3 Results

This section presents the results of our analysis. A descriptive summary of the results is first presented followed by the results of Spearman's correlation analysis and non-parametric hypothesis tests.

3.1 Summary of responses

A summary of the building-related and respondents' personal and demographic characteristics evaluated in this study are presented in Tables 2 and 3. There are relatively similar distributions between genders, ownership status and length of residency. Most of the respondents (90.6%) were between 20-49 years old. Due to the uneven distribution of sample size, the six groups of occupant age were converted to four groups as shown in Table 2. Many (69.0%) lived with other occupants, 9.4% were living with children and 16.9% had pets. When asked to describe their relationship with their neighbors, 34.4% indicated they had good relationships with other neighbors (same floor or downstairs) while only 19.4% of respondents specified that they had good relationships with their upstairs neighbors. In response to a question asking whether or not respondents are willing to pay for a suite with better noise insulation, 44.1% answered "yes", while 24.0% and 31.9% answered "no" and "not sure," respectively.

The majority of the respondents have a one-bedroom suite (52.6%) and many of the suites (57.0%) are in buildings that are 6-10 years old. The five groups of building age are converted into three groups for better distribution of sample size among groups. The majority of respondents (59.6%) indicated that their suite faces a major roadway with four or more lanes. Approximately one-third of the respondents indicated that their suites are located adjacent to or across from elevators. Using the methods described in Section 2, we estimate that, out of 187 respondents, the majority of the suites (87.2%) are located in buildings with large window areas. We also estimate that 63.0% of the suites are located in

Table 2: Summary of personal and demographic characteristics. Where the sample size is less than 213, the exact number of responses is indicated in brackets.

Gender		Age	
Male	43.2%	18-20 years	0.9%
Female	55.9%	21-29 years	38.5%
Prefer not to say	0.9%	30-39 years	36.6%
Ownership		40-49 years	15.5%
Rent	45.5%	50-59 years	5.2%
Own	53.5%	≥60 years	2.4%
Other	1.0%	Prefer not to say	0.9%
Length of residency		Age – four groups (N=211)	
<6 months	12.2%	18-29 years	39.8%
6-12 months	13.6%	30-39 years	37.0%
1-3 years	32.8%	40-49 years	15.6%
3-5 years	20.7%	≥50 years	7.6%
>5 years	20.7%	Relationship with upstairs neighbors (N= 212)	
Living with other occupants		Good	19.4%
Yes	69.0%	Neutral	72.6%
No	31.0%	Bad	8.0%
Living with children (< 18 years old)		Relationship with neighbors on the same floor or downstairs (N= 212)	
Yes	9.4%	Good	34.4%
No	90.6%	Neutral	62.7%
Have pets		Bad	2.8%
Yes	16.9%	Willingness to pay	
No	83.1%	Yes	44.1%
Willingness to pay		No	24.0%
Yes	44.1%	Not sure	31.9%
No	24.0%		
Not sure	31.9%		

Table 3: Summary of building-related characteristics. Where the sample size is less than 213, the exact number of responses is indicated in brackets.

Type of apartment		Window size (N= 187)	
Studio	4.7%	Small (<50% of wall area)	12.8%
One-bedroom	52.6%	Large (>80% of wall area)	87.2%
Two-bedroom	33.3%	Located near elevators	
Three or more bedrooms	9.4%	Yes	39.9%
Building age (N= 205)		No	60.1%
≤5 years	4.0%	Located near garbage chute	
6-10 years	57.0%	Yes	33.3%
11-15 years	18.0%	No	66.7%
16-20 years	18.0%	Main door weather-stripped (N=211)	
> 20 years	3.0%	Yes	22.8%
Building age – three groups (N= 205)		No	33.2%
≤10 years	61.0%	I do not know	43.1%
11-15 years	18.0%	Not applicable	1.0%
>15 years	23.0%	Balcony door weather-stripped (N=212)	
Facing roadway with 4 or more lanes		Yes	50.5%
Yes	59.6%	No	8.0%
No	40.4%	I do not know	29.7%
Within 150 m radius of ongoing construction (N= 200)		Not Applicable	11.8%
Yes	63.0%	Windows weather-stripped (N=211)	
No	37.0%	Yes	50.7%
Have balcony		No	11.4%
Yes	84.0%	I do not know	36.5%
No	16.0%	Not applicable	1.4%

buildings that are close to ongoing construction, thus highly exposed to construction noise. In order to determine noise insulation levels of doors and windows, and their effectiveness in reducing sound exposure, questions regarding weather-stripping were included. Approximately 50.7% of respondents have weather-stripped windows and balcony doors, while only 22.8% indicated that their main door (door to hallway) was weather-stripped.

3.2 Distribution of annoyance levels with noise sources

Figure 1 shows a summary of responses that indicated that they were at least slightly annoyed by individual noise sources. 79.8% of respondents were annoyed to some extent by one or more outdoor noise sources and 70.0% of respondents were annoyed with one or more sources of indoor noise. It can be seen that more respondents (> 70%) indicated annoyance with traffic noise compared to other outdoor noise sources. For indoor noise sources, the most frequently reported annoyance was with airborne noise from shared spaces followed by airborne noise through walls, and noise from heating and cooling systems. Comparing overall annoyances, the results showed that more respondents indicated annoyance with outdoor sources compared to indoor sources.

For the open-ended questions, respondents were asked to report any additional sources of noise they hear in their suites that were not included in the closed-ended questions. Respondents identified aircraft, trains, pets, renovation of neighbors' suites, emergency vehicles, occupants in short-term rentals or Airbnb guests, garbage trucks, fire/smoke alarm, outdoor noise traveling through the ventilation system,

parking garage, cannons from a nearby historic site, and neighbor's AC unit as additional noise sources. While some of these fit into the indoor/outdoor categories identified in the study, we think it is important to present all noise sources reported as "additional" by the respondents. Respondents who specified short-term renters' suites as a source of noise in the open-ended questions also indicated loud and inconsistent noise coming from these suites and that short-term occupants make less effort to keep their noise levels down compared to long-term occupants.

3.3 Which noise sources influence overall annoyance?

The Spearman's correlation analysis was performed to identify which noise sources are important for overall noise annoyance. The results, presented in Figure 2, show that annoyance with traffic has the highest significant correlation with overall outdoor annoyance (Spearman's correlation coefficient = 0.64, $p = 0.000$). Annoyance with construction and neighborhood noise have lower levels of correlation with overall annoyance. Annoyance with weather noise, however, has no significant correlation with overall annoyance. It is also worth noting that significant correlations are observed between annoyance with traffic noise and annoyance with other noise sources. For overall indoor annoyance, significant correlations are observed between annoyance with many individual noise sources and overall annoyance. Airborne noise through floors/ceilings, has the highest level of correlation (Spearman's correlation coefficient = 0.47, $p = 0.000$). Annoyance with noise from service installations have strong significant correlations. Annoyance with noise from water installations, and heating and cooling systems, showed

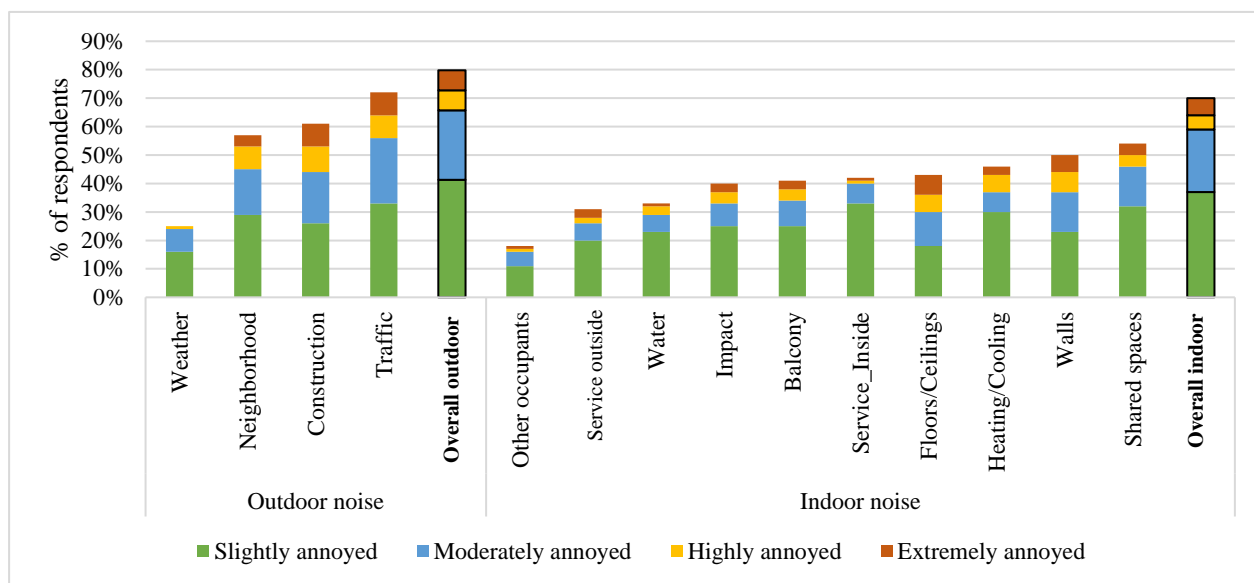


Figure 1: Summary of annoyance levels with indoor and outdoor noise sources.

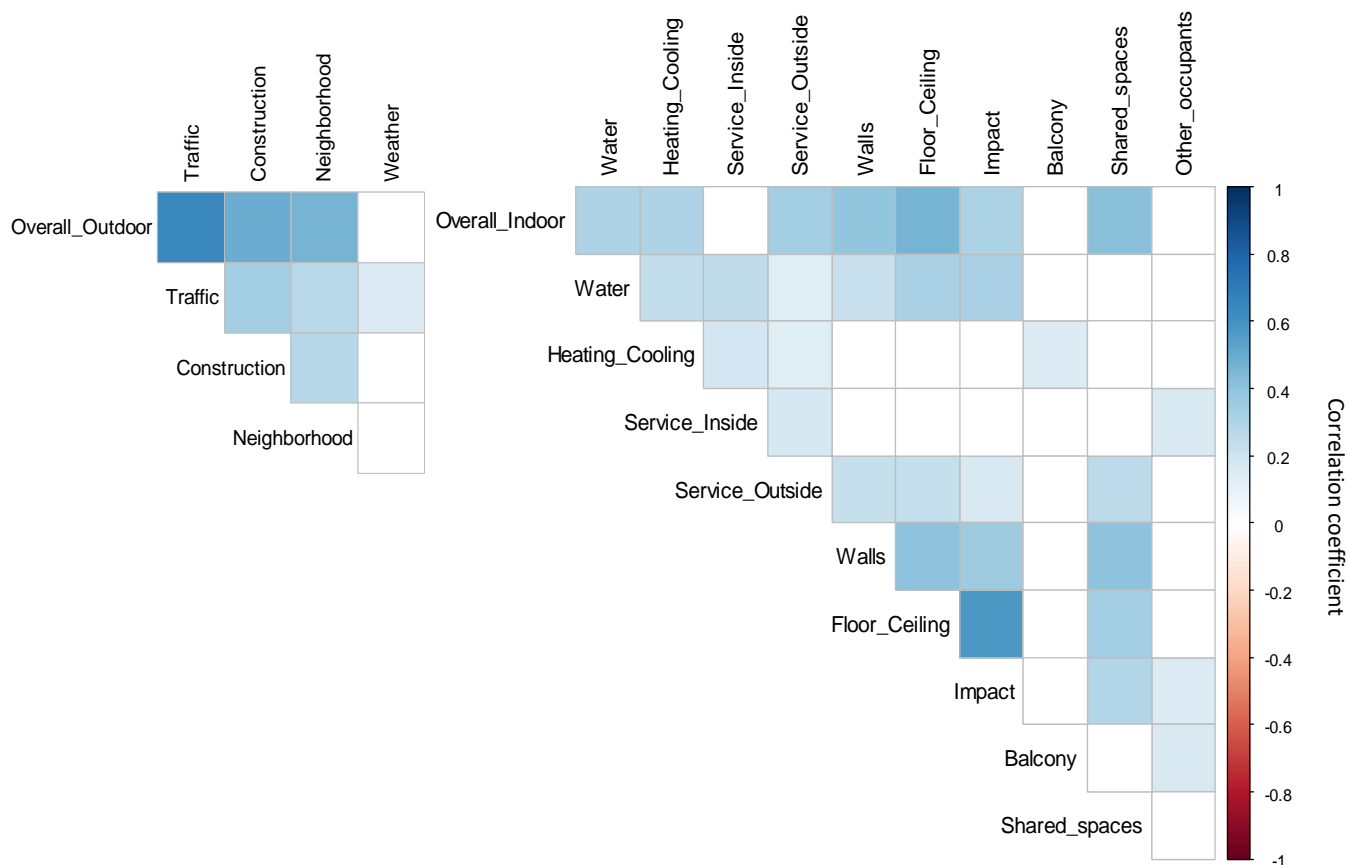


Figure 2: Results of correlation analysis between individual and overall outdoor noise annoyance (left) and individual and overall indoor noise annoyance (right). Empty cells indicate no significant correlation.

weaker, but still significant, correlations. Noise from service installations inside suite, neighbors' noise from balconies and noise from other occupants inside suite have no significant correlations with overall indoor noise annoyance. It can thus be concluded that indoor noises coming from sources outside

one's suite are more problematic for overall annoyance with indoor noises.

Looking at individual noise sources in Figure 2, significant correlations are found in annoyance between water installations and neighbors' noise (via airborne noise

through walls and floors, and impact noise), and service installations outside suite and neighbors' noise. There are also significant correlations between annoyance with other occupants in their own suite and annoyance with service installations inside suite, impact noise and noise from balconies.

3.4 Schedule analysis

In order to identify the time of day that the individual noise sources are the loudest, respondents were asked to report periods of the day (morning, afternoon, evening and night) that the individual noise level is typically the highest. In parallel, respondents were also asked to specify their typical weekday, and weekend schedule and indicate periods that they are typically asleep, awake at home and away from home. In addition to identifying noise trends, information

regarding the schedule of respondents and perceived loud periods allowed for the identification of noise sources that cause disturbance to sleep and annoyance and disturbance to other activities when respondents are awake but at home. This information also allowed us to assess the appropriateness of having higher noise level limits set by many guidelines during daytime (7:00 – 23:00) compared to nighttime (23:00 – 7:00) based on the assumption that noise exposure during the daytime will not affect sleep. The responses are summarized in Figure 3. The bar charts show typical occupancy trends and sleep schedules of the respondents during weekdays and weekends. While many respondents reported being away during the daytime and asleep during nighttime, it is important to note that there are still a number of people that do not follow this schedule.

The bubble plot in Figure 3 shows that some noise sources are consistently loud throughout the day, while some

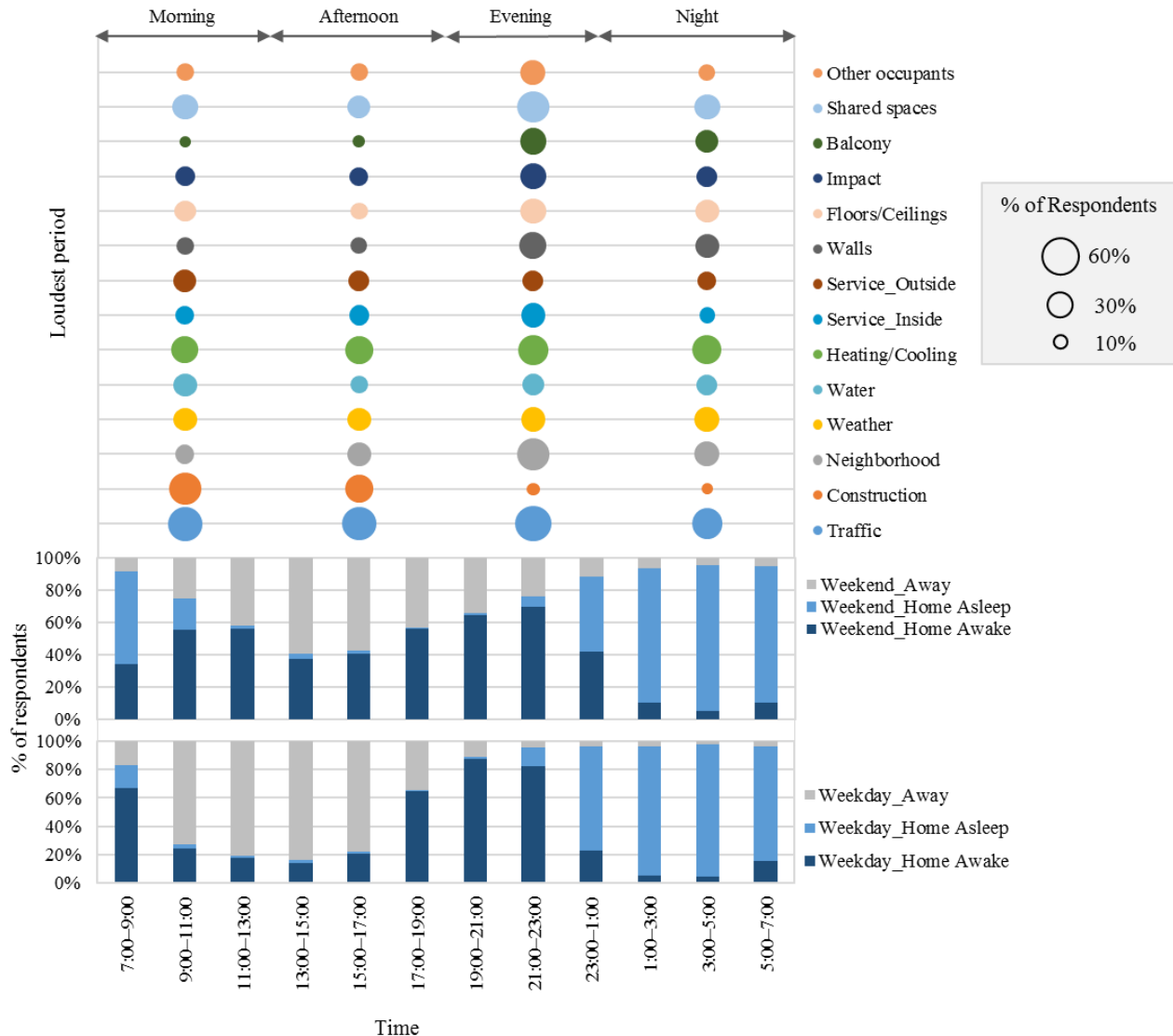


Figure 3: Comparison of reported loud periods and respondents' daily schedule. The area of the bubble corresponds to the number of respondents who indicated that the particular noise source is the loudest during the specific period.

other noises are loud only during specific periods. For instance, traffic, and heating and cooling system noises were reported to be consistently loud throughout the day while construction noise is reported to be loud typically during mornings and afternoons, and outdoor neighborhood noise is reported to be loud mostly during evenings and nights. In addition, except for noise from construction, outdoor neighborhood and balconies, the majority of respondents indicated that noise from most sources are equally loud during weekdays and weekends. For construction, 73.9% of respondents who hear construction noise indicated that it is louder during weekdays compared to weekends while outdoor neighborhood noise and noise from balcony were reported as the loudest during weekends by 48.3% and 50.0% of respondents respectively). This shows that most respondents are exposed to perceived loud noises from multiple indoor and outdoor sources in their suites irrespective of the time of day and day of the week.

3.5 Which building and non-building related factors affect acoustic annoyance?

To identify any correlations among building-related characteristics and suite properties, we first performed a correlation analysis on the building-related characteristics. The results of Spearman’s correlation analysis are presented in Figure 4. Our results show that older buildings are low-

rise, have smaller windows and are in closer proximity to ongoing construction compared to newer ones. In addition, more suites in older buildings do not have balconies, are not facing major roadways and have more bedrooms compared to suites in newer buildings. Building age does not have any correlation with weather-stripping (WS) windows/doors and proximity to elevators and garbage chutes.

Results of the correlation and statistical hypothesis test are presented in Tables 4 and 5. Note that only significant results are shown for a concise presentation of the tables. Spearman’s correlation analysis shows that there is a significant negative correlation between floor level and annoyance with traffic, construction, outdoor neighborhood and overall outdoor noises. There is, however, a significantly positive correlation between floor level and annoyance with weather-induced noise. The statistical test results indicate that building-related factors, such as windows size, proximity to ongoing construction, apartment type and building age significantly affect annoyance with outdoor noises while none of the personal and demographic characteristics significantly affect annoyance with outdoor noises. Contrary to our expectation, respondents in buildings with smaller windows reported higher annoyance with outdoor noise. As shown in Figure 4, there is a negative correlation between window size and, building age. Buildings with small window are much older (average 20 years) than those with larger windows (average 10 years) (Wilcoxon rank-sum test, $W = 3645.5$,

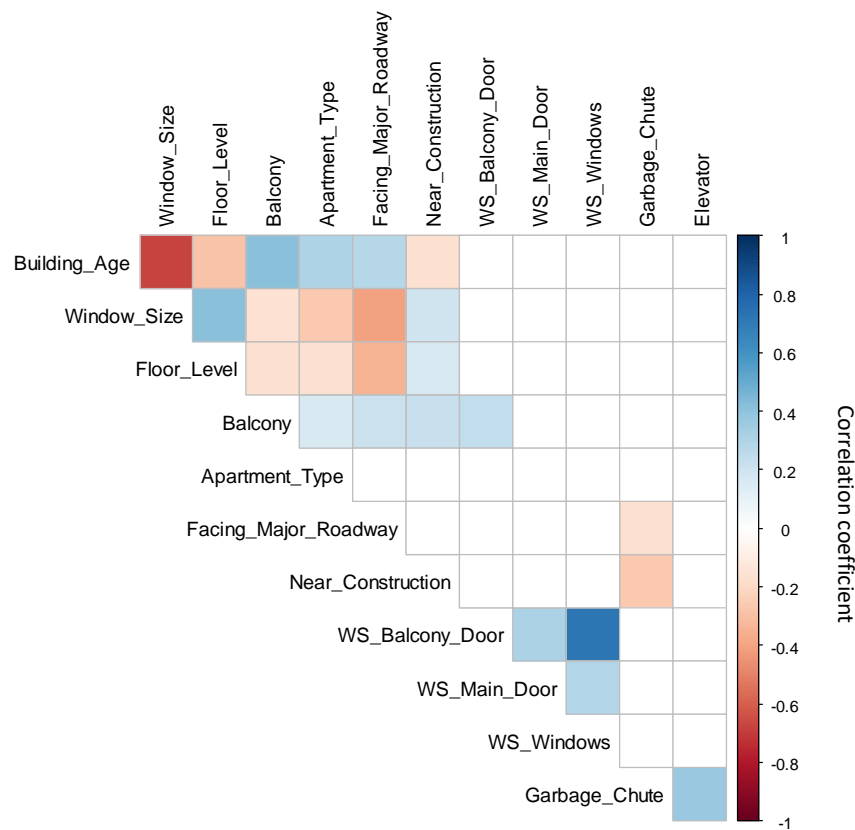


Figure 4: Results of correlation analysis among building characteristics and suite properties. Empty cells indicate no significant correlation.

Table 4: Correlation and non-parametric test results for difference in annoyance with outdoor noises (*p<0.05; **p<0.01; ***p<0.001).

	Overall	Traffic	Construction	Neighborhood	Weather
Spearman's rank correlation test					
Floor level	-0.239***	-0.160*	-0.188**	-0.265***	0.180**
Wilcoxon rank-sum test					
Proximity to a major roadway	5295.5	6137.5	5065.5	5183.5	6168.0*
Window size	2385.5	2177.5	3051.0***	2501.5*	1610.0
Proximity to ongoing construction	4640.0	5414.0*	5806.0**	4999.0	3923.5*
Kruskal-Wallis test					
Apartment type	7.9*	7.3	12.3**	6.3	0.4
Building age	5.8	5.7	37.6***	7.9*	5.2
Dunn's test					
Apartment type					
Studio & 2-bedroom	-2.5*		-1.5		
Studio & ≥3 bedrooms	-2.0*		-2.2*		
1 & 2-bedroom	-1.7		-2.4*		
1 & ≥3 bedrooms	-0.8		-2.9**		
Building Age					
≤ 10 & 11-15 yrs.			-4.0***	-2.1*	
≤ 10 & >15 yrs.			-5.5***	-2.3*	

p < 0.001). This fits well with our finding that occupants in older buildings express higher levels of annoyance compared to those in newer buildings. The post-hoc test shows that the difference is observed between respondents in buildings that are ≤10 years and ≥10 years. For apartment type, the post-hoc tests show that annoyance levels in studio and one-bedroom suites are significantly lower than suites with two or more bedrooms. This might be because respondents in suites with two or more bedrooms are mostly located in older buildings (as shown in Figure 4) where annoyance level is generally higher than newer buildings. It is important to note that having a balcony and weather-stripping balcony door/windows have no significant effect on annoyance with outdoor noises.

For indoor noises, both building-related factors and respondents' personal and demographic characteristics significantly affect annoyance levels. Those who are living with other occupants and those who have pets are significantly less annoyed by overall indoor noise. Age, length of residency and ownership are also significant predictors of annoyance with indoor noises coming from neighbors. Older respondents and those who have lived longer in their suites showed higher annoyance levels than their counterparts. Owners also indicated higher annoyance levels than renters. Relationship with neighbors is also a significant predictor of annoyance with indoor noises. Those who expressed having good relationships with their neighbors are less annoyed with noise from neighbors and overall indoor noise than those who reported neutral or bad relationships. In addition, those who are willing to pay for better noise insulation are significantly more annoyed by neighbors' noise than those who were not willing or hesitant to pay. The results show that gender and living with children are not significant predictors of annoyance.

Examining building-related factors, respondents in older buildings showed higher annoyance with noise from water installations, and heating and cooling systems. These respondents also reported higher annoyance with noise from neighbors. Those in suites close to elevators and garbage chutes indicated higher annoyance with noise from service installation outside their suite compared to those in suites that are not close to these services. There was no significant difference in annoyance between those who weather-stripped their door to the hallway and those who did not. We found a significant negative correlation between floor level and overall indoor annoyance. In addition, those in buildings that are close to ongoing construction expressed a significantly higher annoyance with airborne and impact noise transmitted through floors compared to those that are not exposed to construction noise.

3.6 Effect of noise on daily activities

Figure 5 shows the reported effects of different indoor and outdoor noises. The most frequently reported effect of noise exposure is sleep disturbance. Approximately 50.2% of respondents indicated that traffic noise disturbs their sleep. Respondents also indicated that noise from construction, outdoor neighborhood, neighbors, and heating and cooling systems also affect their sleep. In addition to sleep disturbance, impacts of both outdoor and indoor noises on mental stress, mood, work/study and relaxation were also specified. Noise from neighbors and outdoor noises have the highest percentage of reported impact on mental stress and mood respectively. The highest percentage of reported impact on work/study is for construction, possibly because construction occurs during the daytime.

Table 5: Correlation and non-parametric test results for difference in annoyance with indoor noises (*p<0.05; **p<0.01; ***p<0.001).

	Overall	Water installation	Heating/ Cooling	Service_ Inside	Service_ Outside	Neighbors					Other occupants
						Walls	Floor/ Ceiling	Impact	Balcony	Shared spaces	
Spearman's rank correlation test											
Floor level	-0.139*	-0.048	-0.128	-0.081	-0.077	-0.023	-0.040	-0.015	0.047	-0.029	-0.054
Wilcoxon Rank-Sum Test W											
Has other occupants	3909.5*	4729.0	4847.0	4873.5	4472.5	4103.5	3886.5*	4197.0	3632.0***	3875.5*	5599.5*
Has pets	2482.0*	3119.0	2998.0	2842.0	2706.0	2840.5	2980.5	3185.0	3645.5	2963.0	3176.0
Has balcony	2779.0	3365.5	2415.0*	3252.0	2897.0	3295.5	3075.0	3382.5	4429.5***	3114.5	2454.0*
Neighbors have balcony	3618.0	4233.5	3446.0	3631.5	3589.5	3782.0	3906.0	4192.5	5115.0***	3522.0	3086.5*
Garbage chute	4766.5	4755.5	4746.5	5541.0	6509.5***	5352.5	5251.0	5205.0	5091.0	5210.5	5442.0
Elevator	5839.5	5989.0	5321.5	5777.0	7222.0***	5702.5	6042.0	5858.5	5743.0	5716.5	5995.5
Ownership	4669.0*	4879.0	5401.0	5457.5	5665.0	5130.0	4088.5***	4219.5***	3825.0***	4382.0**	5955.5
Window size	1913.5	2185.5	2263.0	1899.0	1859.0	2045.0	2132.5	2127.5	1612.5	1369.5*	1951.0
Proximity to ongoing construction	5397.0	5227.0	4774.0	4284.5	4626.0	5224.5	5848.0***	5400.0*	5301.0	5147.5	4703.0
Kruskal-Wallis Test											
Age	2.9	2.3	0.6	1.7	1.7	3.1	13.2**	15.7***	17.5***	1.6	3.2
Apartment type	2.9	4.3	3.3	1.4	2.7	2.7	1.2	4.2	13.4**	4.4	9.9*
Time lived in suite	9.6*	8.2	3.3	1.8	2.3	9.3	18.2***	13.4**	28.4***	6.4	5.3
Relationship with upstairs neighbors	19.0***	6.1*	2.2	2.6	0.2	4.2	34.8***	26.2***	10.9**	14.5***	6.0*
Relationship with other neighbors	14.1***	2.1	1.5	0.8	3.1	14.2***	8.3*	1.6	1.9	9.5**	0.4
Weather-stripping											
Balcony door	3.2	6.0	7.2	1.2	1.0	2.8	3.1	1.6	26.8***	2.6	2.9
Building age	1.5	9.7**	9.1**	4.2	1.9	1.6	2.6	6.9*	11.6**	11.1**	0.4
Willingness to pay	4.0	1.6	3.2	0.3	4.8	6.5*	12.5**	8.2*	1.9	6.2*	1.5
Dunn's test											
Age											
<30 & 30-39 yrs.							-2.1*	-2.4*	-3.1**		
<30 & 40-49 yrs.							-3.2**	-2.8**	-3.1**		
<30 & ≥50 yrs.							-2.3*	-3.1**	-2.9**		
Apartment type											
1 & ≥3 bedrooms									3.3***		-3.1**
2 & ≥3 bedrooms									2.3*		-2.2*
Length of residency											
<6 mos. & 6-12 mos.	-2.5*						-1.7	-0.2	-1.0		
<6 mos. & 1-3 yrs.	-2.8**						-2.7**	-1.7	-2.1*		
<6 mos. & 3-5 yrs.	-1.9						-3.0**	-2.0*	-3.4***		
<6 mos. & >5 yrs.	-2.6**						-4.1***	-3.1**	-4.6***		
6-12 mos. & 3-5 yrs.	0.9						-1.1	-1.8	-2.4*		
6-12 mos. & >5 yrs.	0.1						-2.3*	-2.9**	-3.6***		
1-3 yrs. & > 5 yrs.	0.1						-2.0*	-1.9	-3.4***		

Relationship with upstairs neighbors									
Good & Neutral	-2.6**	-0.5			0.9	1.9	1.3	1.5	0.3
Good & Bad	-4.3***	-2.4*			-5.5***	-5.1***	-3.3***	-3.8***	-2.0*
Neutral & Bad	-3.1**	-2.3*			-5.6***	-4.4***	-2.8**	-3.2**	-2.5*
Relationship with other neighbors									
Good & Bad	-3.7***				-3.8***	-2.7*			-2.9**
Neutral & Bad	-3.2**				-3.6***	-2.9**			-2.4*
Weather-stripping - balcony door									
Yes & Do not know							2.5*		
Building age									
≤ 10 & 11-15 yrs.		-3.1**	-2.2*				-2.6**	-1.1	-0.1
≤ 10 & >15 yrs.		-0.5	-2.5*				-0.4	2.9**	3.2**
11-15 & >15 yrs.		2.2*	-0.1				1.9	3.2**	2.6**
Willingness to pay									
Yes & No					1.7	3.4***	2.9**		2.5*
Yes & Not sure					2.4*	2.1*	1.2		1.4

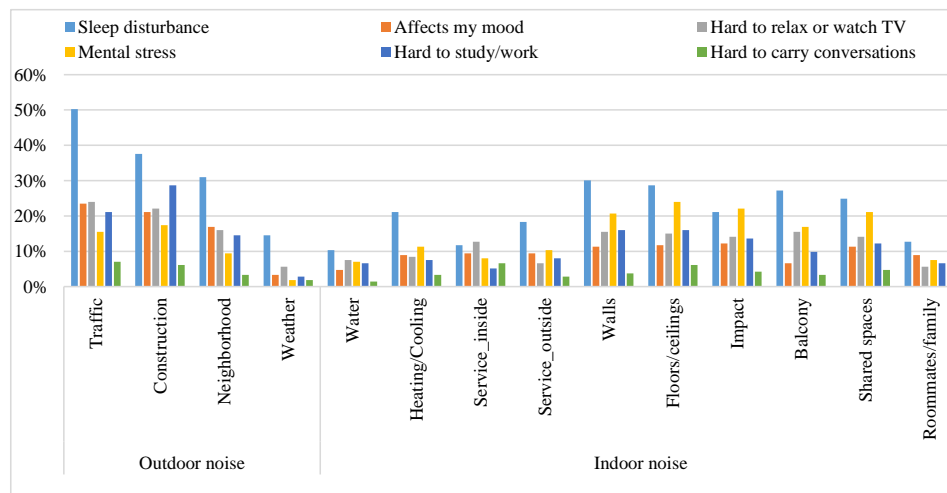


Figure 5: Reported effects of noise on respondents.

3.7 Noise mitigation measures

As shown in Figure 6, many respondents (90.1%) indicated closing their windows as an outdoor noise mitigation strategy. Other mitigation strategies were less commonly reported. It is important to note that 38.0% of the respondents specified playing music/TV loudly to mask noise. One respondent stated that they keep their balcony door open for fresh air but play loud music on their balcony to mask outdoor noise. Respondents also indicated that they leave the building (23.5%) and adjust their schedule (16.4%) to avoid noise which shows that occupants have very limited options to mitigate noise. In the open-ended question, respondents stated additional mitigation strategies. These include legal

action, changing rooms or location within a room, avoid using certain spaces, such as balconies, using sound blocking curtains, installing acoustic foams and other acoustic retrofits. Some respondents specified turning off their HVAC or covering supply/return grilles, or regularly maintaining their HVAC system to reduce noise that might come from unmaintained HVAC systems, while others reported using noise from their HVAC to mask noise coming from outside their suite. A few respondents also stated that their building management is doing very little to address noise complaints. While not necessarily a mitigation strategy, more than 60% of the respondents indicated that they limit noise inducing behavior.

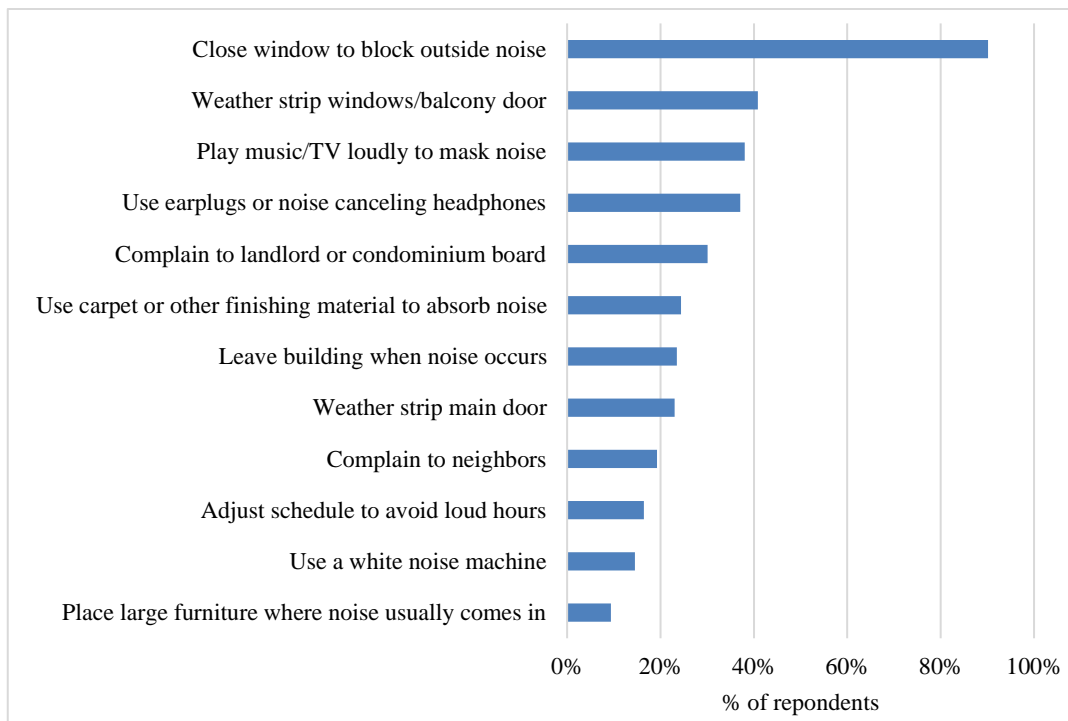


Figure 6: Summary of noise mitigation measures.

4 Discussion and recommendations

In contrast to the findings of some studies [18,19,26], the current study found that outdoor noises, specifically noise from traffic, construction and neighborhood activities, are more frequently experienced and cause more annoyance and sleep disturbance than indoor noises. We postulate that one of the reasons for this is the lack of regulation on façade sound insulation in the provincial building code [28], which gives developers little incentive to implement measures that can improve the acoustic performance of façades. The above-mentioned studies [18, 19, 26] are also conducted in Europe and Asia where there are relatively stringent energy code requirements with strict enforcement standards [29]. Better energy performance requirements, such as requirements for higher thermal insulation and improved airtightness, can contribute to the improvement of the acoustic performance of buildings [30]. The findings show that incorporating sound insulation requirements for building façades in the local

building code is imperative. To reduce costs associated with noise control, requirements can be flexible for the upper floors. However, it is important to note that improving façade insulation can also decrease noise from neighboring suites' coming from inside the neighbors' suites or their balconies, thus additional measures should be taken to reduce noise coming from neighboring balconies in upper floors. Improving the acoustic performance of the façade can also improve the energy performance of the building as well as occupants' thermal comfort [30]. Similarly, a better energy efficiency standard can improve acoustic comfort.

Contrary to the results of some studies [9, 13, 31], the current study did not find any significant difference in annoyance levels with traffic and overall outdoor noise between suites that are facing a major roadway and those that are not. Bluhm et al. [32] suggest that the orientation of bedrooms is only important when there is a relatively lower traffic noise level. At high exposure levels, Bluhm et al. found that suites that are facing a major roadway and those

that are not both expressed similar annoyance levels. Considering the high percentage of people who reported annoyance, and disturbance of sleep and other activities due to traffic noise, our findings indicate that respondents are exposed to high levels of traffic noise.

Our results show that the existence of balconies does not have any reduction effect on reported annoyance levels with outdoor noise, and, in fact, can increase exposure and thus annoyance to neighbors' noise from balconies. If not properly designed, balconies will not reduce outdoor noise levels, and can actually increase noise levels due to reflections from the ceiling and other hard surfaces on balconies [33]. Similarly, weather-stripping windows and balcony doors did not affect annoyance levels. Without any additional measures, especially proper selection of materials at the design stage or more rigorous retrofit measures, such as increasing insulation and adding absorptive materials, weather-stripping or sealing windows and doors alone will have minimum sound attenuation effects (typically 1 – 5 dB) [34, 35]. These results show that careful consideration of all façade components is important for better noise reduction.

While outdoor noises were found to be more problematic than indoor noises, a significant number of people still reported annoyance with indoor noises. This is likely due to the fact that, until 2020, the provincial building code did not include requirements for flanking sound transmission, and were given in terms of sound transmission class (STC) instead of apparent sound transmission class (ASTC) which takes into account flanking transmission paths [28]. Noise through walls and common building areas were thus reported more annoying than other indoor noise sources despite the minimum STC requirement of 50 for airborne sound insulation of indoor assemblies [28]. Similarly, respondents in suites close to elevators and garbage chutes expressed annoyance with the noise produced by these sources despite a minimum requirement of STC rating of 55. The building code also gives the option to show compliance to the requirements using laboratory measurements or preapproved assemblies that meet the requirements. The field performance of assemblies can, however, vary from that in laboratories and might not provide adequate sound insulation.

In addition, annoyance was reported for noise sources that are not currently regulated by the building code, including impact noise, noise from heating and cooling systems, and service installations inside suites. The current study also found that those who are exposed to high levels of outdoor noise indicate more annoyance towards indoor noises. Respondents in lower floors and those in buildings close to ongoing construction reported higher annoyance levels with indoor noises. This is in line with the Park and Lee study [36] which found that, instead of masking intermittent indoor noises, exposure to higher outdoor noise levels resulted in higher annoyance ratings and anger due to floor impact noise. These findings provide further proof for the need to carefully consider and implement both façade and indoor airborne and impact sound insulation.

This study identified disturbance of work/study as one of the important effects of noise exposure on MURB occupants. National and international noise guidelines recommend

higher daytime background noise level limits for residences (typically 35 – 45 dBA) compared to enclosed offices (typically 30 – 35 dBA) based on the assumption that people do not work from their residences [37, 38]. WHO, for instance, states that the most important effects of noise in residences are sleep disturbance, annoyance and communication interference [6]. With a growing number of people working from home [39, 40], requirements for quieter residences should be implemented to limit the effects of noise on productivity. In addition, assumptions that sleep disturbance will not occur during daytime should be reviewed as our findings suggest that people have varying schedules and many people experience sleep disturbance during the daytime.

The results also suggest that poor indoor acoustic conditions in MURBs can result in occupants' actions that can negatively impact the indoor environmental conditions of their buildings as well as energy-adverse actions. Reduction in indoor air quality is one consequence of noise mitigating actions, such as turning off HVAC, covering supply/return grilles, or closing windows. Other actions, such as keeping the windows closed or keeping the HVAC on to mask other noise, can increase the heating and cooling demand of buildings. More importantly, some actions, such as playing loud music to mask noise, can exacerbate the acoustic condition in buildings which shows the importance of noise control in MURBs.

Despite existing evidence suggesting that people can adapt to noise [9, 41, 42], our findings show that length of residency does not have an effect on annoyance with outdoor noise. Weinstein [43] suggests that people tend to form opinions about the noise conditions in the first few days or few weeks and tend to stick to their initial opinion even if the actual effect of noise on the disturbance of their daily activity decreases. The current study also found that annoyance with indoor noise, particularly from neighbors, increased with increasing length of residency. One explanation for this is that, as a number of respondents indicated, short-term occupants have a temporary mindset and make less effort to reduce the noise they make, and thus are less likely to be disturbed by noise from others. Another explanation is the expectations of future noise levels. Residents who have been exposed to growing noise levels over past periods fear that the noise will keep increasing in the future [8,44]. With limited or no options to mitigate noise, occupants thus express more annoyance in anticipation of the noise increase.

5 Conclusions

This paper describes general acoustic comfort levels in MURBs, identifies important sources of noise in MURBs and presents factors that impact occupants' annoyance with noise and other effects of noise on occupants. Our findings indicate that many occupants are experiencing acoustic discomfort with both indoor and outdoor noises. Among the studied building-related factors, building age, type of apartment, floor level and proximity to ongoing construction were found to impact annoyance with outdoor noise. Proximity to a major roadway, existence of balcony, and weather-stripping had no

influence on annoyance with outdoor noise. For indoor noise annoyance, the existence of balcony, apartment type, proximity to elevators and garbage chute had an impact. While age, ownership, Length of residency and willingness to pay for better acoustic conditions had negative impacts on annoyance with indoor noises, living with other occupants, having pets and better relationships with neighbors reduced annoyance levels. We found that traffic, construction and noise from outdoor neighborhood activities, cause more annoyance and sleep disturbance compared to indoor noises. For indoor noise, airborne noise from neighbors, and noise from heating and cooling systems were identified as more annoying than other sources. Our findings also show that lack of proper noise control options can lead to some noise mitigating behaviors which can have negative effects on indoor air quality and building energy consumption, as well as worsen the overall acoustic condition in buildings. While

the current study identifies important factors that impact acoustic comfort, it is based on subjective assessment only. Future research can combine field acoustic measurements with subjective assessments to identify the relationship between building features, indoor noise levels and occupant comfort.

Acknowledgments

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Appendix

Table 6: Survey questions and response options.

Questions	Response options
1. Gender	Male; Female; Prefer not to say
2. Age	18 – 20 ; 21 – 29; 30 – 39; 40 – 49; 50 – 59; 60 or older; prefer not to say
3. For how long have you lived in your current apartment?	< 6 months; 6 – 12 months; 1 – 3 years ; 3 – 5 years ; > 5 years
4. What is your apartment ownership status:	I am renting; I own the apartment; Other (please specify): _____
5. Please indicate your typical schedule during weekdays. • 7am – 9am; 9am – 11am; ...	Home – asleep; Home – awake; Away
6. Please indicate your typical schedule during weekends. • 7am – 9am; 9am – 11am; ...	Home – asleep; Home – awake; Away
7. Please enter your street address.	_____
8. What is your apartment type	Studio; One-bedroom; Two-bedroom; Three or more bedrooms
9. How many floors does your building have?	_____
10. Which floor is your unit located on? (Ground floor = 1)	_____
11. Is your apartment located near (adjacent to or across from the hall) an elevator?	Yes; No
12. Is your apartment unit located near (adjacent to or across from the hall) a garbage chute?	Yes; No
13. Does your apartment unit have a balcony?	Yes; No
14. Do any of the apartment units adjacent to your unit have balconies?	Yes; No
15. Is your apartment unit adjacent a roadway with 4 or more lanes (2 lanes each way)?	Yes; No
16. Please indicate if doors windows are weather-stripped. • Door to hallway • Windows • Balcony door	Yes; No
17. Do you have dog(s), bird(s) or other noisy pets in your apartment unit?	Yes; No
18. Are you currently living with anyone else?	Yes; No
19. Please specify the number of full-time occupants in your unit. • Adults (18 years or older); 11 – 17 years old; 6 – 10 years old; 1 – 5 years old; 1 year old or younger	(Specify number for each age group)
20. How would you describe your relationship with your upstairs neighbors?	Good; Neutral; Bad

21.	How would you describe your relationship with your neighbors on your floor or downstairs neighbors?	Good; Neutral; Bad
22.	Thinking about the last 12 months in your apartment, how much were you bothered or annoyed by these outdoor noise sources? <ul style="list-style-type: none"> • Traffic • Construction • Outdoor neighborhood activities: restaurants, people on the street, etc. • Weather (e.g., wind) • Other (please specify): 	Not annoyed; Slightly annoyed; Moderately annoyed; Highly annoyed; Extremely annoyed; Not applicable
23.	Thinking about the last 12 months in your apartment, how much were you bothered or annoyed by overall outdoor noise?	Same as above
24.	Thinking about the last 12 months in your apartment, how much were you bothered or annoyed by these Indoor noise sources? <ul style="list-style-type: none"> • Water installations: plumbing, flushing toilet, shower, etc. • Heating/cooling: heaters, air conditioning, air supply grille, etc. • Service installations inside unit: laundry machine, kitchen fan, etc. • Service installations outside unit: elevator, garbage chute, etc. • Noise through walls: people talking, pets, etc. • Footsteps, moving furniture and other impact noise • Noise through floors/ceilings: people talking, pets, etc. • Noise from balconies • Noise from shared spaces: e.g., hallways and stairways. • Other occupants in the same unit: talking, other activities • Other (please specify): 	Same as above
25.	Thinking about the last 12 months in your apartment, how much were you bothered or annoyed by overall indoor noise?	Same as above
26.	Please indicate the time(s) of day when the following noise is the highest. Please select all that apply. (Same outdoor and indoor noise source options as question #22 and #24)	Continuous; 7am– 12pm; 12pm–7pm; 7pm–11 pm; 11pm–7am; Not applicable
27.	Please indicate the day(s) when the following noise is the highest. (Same outdoor and indoor noise source options as question #22 and #24)	Weekday; Weekend; Both; Not applicable
28.	Please indicate any effects each noise source might have on your daily activities. Please select all that apply. (Same outdoor and indoor noise source options as question #22 and #24)	Sleep disturbance; Hard to work/study; Hard to relax or watch TV; Hard to carry conversations; Affects my mood; Mental stress; No effect; Not applicable
29.	Do you use any of the following noise mitigation measures in your unit? <ul style="list-style-type: none"> • Close the window to block outside noise • Weather strip windows or balcony door • Weather strip main door • Complain to neighbor about the noise • Complain to landlord or board about the noise • Use carpet or other finishing material to absorb noise • Place large furniture where noise usually comes in • Leave building when the noise occurs • Adjust schedule to avoid loud hours • Use a white noise machine • Use earplugs or noise-canceling headphones • Play music/TV loudly to mask the noise • I/We limit noise inducing behavior (decrease music/TV volume, don't use vacuum cleaner at night, etc.) • Other (please specify): _____ 	Yes ; No
30.	Is there anything you would like to add regarding the acoustic comfort in your unit?	_____
31.	Would you pay more for a unit with better noise insulation?	Yes; No; Not sure

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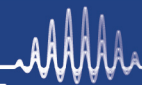
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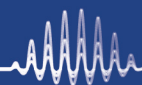
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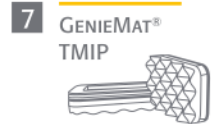
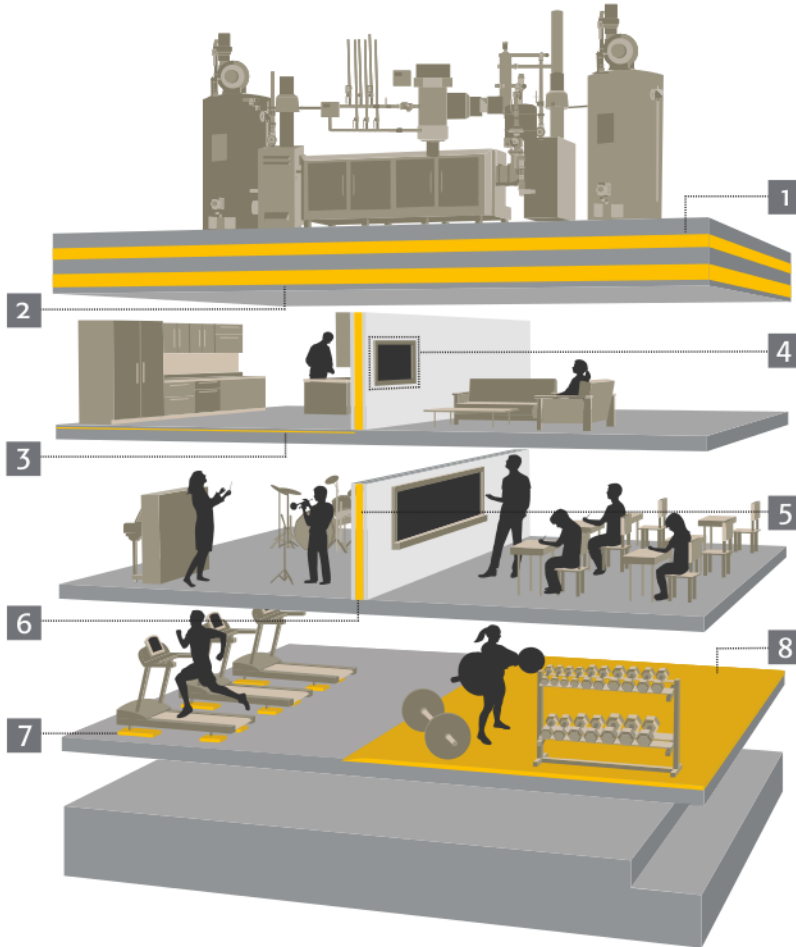


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EFFECTS OF ALTERED INTENSITY FEEDBACK ON SPEECH IN HEALTHY SPEAKERS

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Résumé

Cette étude a examiné le rôle de la rétroaction auditive dans la régulation de l'intensité de la parole chez les adultes en bonne santé. Dix participants ont effectué cinq tâches de production de la parole (voyelle, lecture de phrases avec/sans instructions d'ignorer la rétroaction, et conversation à une distance d'un/six mètres de l'interlocuteur) dans diverses conditions de rétroaction et d'intensité altérée (RIA). Les conditions RIA allaient de plus/moins 2,5, 5, 7,5, 10, 12,5 et 15dB SPL par rapport à la condition équivalente (0dB). Les valeurs d'intensité de la parole obtenues pour chacune des treize conditions RIA ont été soumises à une analyse de régression linéaire et les valeurs de pente et d'interception résultantes ont été comparées. La pente moyenne de la fonction RIA s'est avérée être significativement plus raide pour les tâches de conversation (-0,16) que pour les tâches de lecture (-0,07). Aucune différence de pente n'a été constatée pour la comparaison des tâches de lecture avec et sans instructions d'ignorer les rétroactions altérées ou pour la comparaison des conversations à une distance d'un et six mètres de l'interlocuteur. Il semble que les tâches de discours avec des exigences de communication plus importantes (c'est-à-dire la conversation) montrent des réponses compensatoires plus importantes à la RIA que les tâches avec des exigences de communication plus faibles (la lecture). Les résultats suggèrent que les demandes de la tâche de parole peuvent interagir avec le traitement de la rétroaction auditive pour influencer la régulation de l'intensité de la parole.

Mots clefs : perception, communication, parole, intensité de la parole, rétroaction auditive altérée, rétroaction auditive

Abstract

This study examined the role of auditory feedback in speech intensity regulation in healthy adults. Ten participants completed five speech production tasks (vowel, sentence reading with/without instructions to ignore feedback, and conversation at one/six meter interlocutor distances) under various altered intensity feedback (AIF) conditions. AIF conditions ranged from plus/minus 2.5, 5, 7.5, 10, 12.5, and 15dB SPL relative to the equivalent (0dB) condition. Speech intensity values obtained for each of the thirteen AIF conditions were submitted to a linear regression analysis and the resulting slope and intercept values were compared. The average slope for the AIF function was found to be significantly steeper for the conversation tasks (-.16) than for the reading tasks (-.07). No difference in slope was found for the comparison of the reading tasks with and without instructions to ignore altered feedback or for the comparison of conversations at one- and six-meter interlocutor distances. It appears that speech tasks with greater communicative demands (i.e. conversation) show larger compensatory responses to AIF than tasks with lower communicative demands (reading). Results suggest that demands of the speech task can interact with the processing of auditory feedback to influence the regulation of speech intensity

Keywords: perception, communication, speech, speech intensity, altered auditory feedback, auditory feedback

1 Introduction

The neurological system relies on a variety of factors to regulate and produce speech at an intensity that is appropriate for the communicative situation. Auditory processes, and physical processes are required [1, 2]. The importance of auditory processing for speech is evident during child development when acoustic input heavily influences the speech patterns of pre-lingual children [3-7]. Researchers suggest the low speech intelligibility of hearing-impaired speakers is a result of auditory signal perception impairment [8-10]. In addition, this is described in studies of post-lingually deafened individuals who present with abnormalities in the loudness, pitch, and rate of speech [11].

The use of auditory information in the ongoing control of speech production can be most effectively studied by altering the auditory feedback signal. If, during a speech movement, one experiences unexpected alterations of their sensory feedback (auditory, visual, proprioceptive) the speech-motor system should be able to recognize the incongruence from the motor plan and adjust or compensate accordingly. This adaptive process is thought to involve stored representations of the intended speech output based on previous experiences [12]. Perturbation studies involve altering auditory feedback and measuring responses to brief (~200-500ms) perturbations of the speech signal and existing literature describes this type of compensatory response by healthy speakers (pitch and formant structure perturbations) as an alteration in speech production in the opposite direction to the perturbation (although some studies have also shown following and null responses) [13-15]. Healthy participants

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similarly respond to brief unexpected intensity perturbations by compensating in the opposite direction to the feedback [16, 17].

Altered intensity feedback (AIF) (also referred to as “sidetone amplification” in previous literature [1, 18,19]) involves the presentation of one’s own speech via headphones for the duration of the utterance (in contrast to the brief, typically 200-500ms, alteration in a perturbation paradigm). This type of manipulation causes the participant to continuously hear their speech intensity at an altered (increased or decreased) level. Similar to the perturbation findings, this causes a healthy speaker to adjust their speech intensity in the opposite direction to the alteration, as a presumed compensation response [1, 18-21]. The AIF paradigm enables evaluation of the AIF function or the relationship between changes in speech intensity that is perceived and subsequent changes in speech intensity that is produced. Slope of the AIF function has been observed to range between $-.1$ and $-.15$ with no background noise [1, 18] (See Figure 1 as example of the AIF slope function from Lane and Tranel (1969). Increased slope functions ($-.4$) have been observed when AIF is presented with background noise [1, 18]. When instructed to maintain a constant level of loudness (use the auditory feedback to make compensatory adjustments as needed to maintain a constant level), participants also show an increased ($-.46$) slope function compared to when no instructions are provided [19].

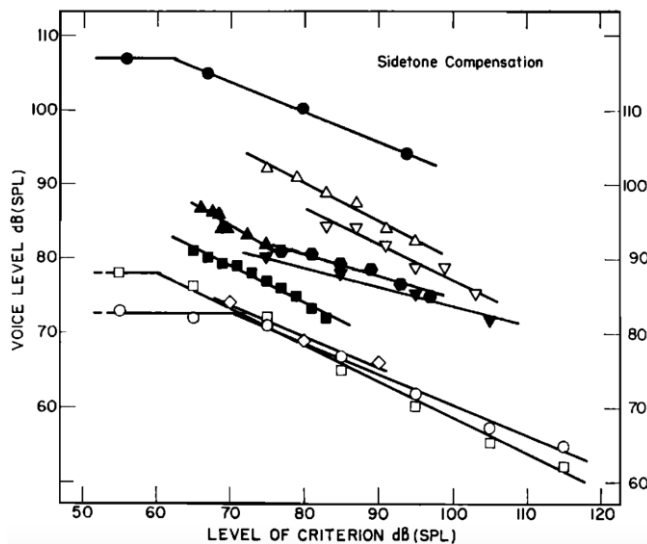


Figure 1: Sample graph depicting the AIF function. Reprinted from Regulation of Voice Communication by Sensory Dynamics, by Lane, Tranel, and Sisson, 1969, retrieved from The Journal of the Acoustical Society of America, 47 (1969) [21].

1.1 Speech task

Average speech intensity can be obtained across a vowel, sentence, and across a breath group or utterance within speech. Quasi-speech tasks include those that do not necessarily represent natural speech (e.g. vowel prolongation and reading). Junqua, Finckle, and Field [22] found speech intensity increased more in background noise (Lombard effect [23]) during conversational speech than in a reading

task. Thus, the nature of the speech task appears to have an influence on the regulation of speech intensity. The effect of speech task on speech intensity regulation is also exemplified by the work of Patel and colleagues [24]. These researchers suggest it is possible that healthy participants may regulate speech intensity (during perturbed feedback) only in speaking contexts requiring a specific linguistic goal, specifically relating to emphatic stress in a sentence. However, it is possible that suprasegmental (intensity regulation across a sentence) and segmental aspects of speech (related to the production of specific vowels or consonants) may be controlled by different mechanisms for which auditory feedback plays different roles [25]. It is unclear if the role of auditory feedback for speech intensity differs depending on the nature of the speech task. Fletcher, Raff, and Parmley [26] and Noll [27] found reduced slope values (within background noise conditions) during monosyllable ($-.25$) and passage readings ($-.3$) respectively, suggestive of a possible attenuation of the AIF effect in conditions lacking a communicative goal. To our knowledge, previous studies have not examined the role of auditory feedback for speech intensity across tasks with differing communicative intent using AIF.

1.2 Distance conditions

In typical conversational settings, the speaker must monitor the environment and their own speech intensity levels in order to compensate for such factors as the distance of the intended listener [23, 28]. In order to do these things, the speaker must have some sort of sensorimotor monitoring process in place to maintain appropriate intensity of speech. The talker-to-listener distance, or interlocutor distance, can cause a speaker to increase their speech intensity with increasing distance [29, 30]. Previous studies have explored the importance of speaking context for speech intensity regulation, with findings consistent with incremental increases in intensity corresponding to increasing interlocutor distances [31-34]. The role of auditory feedback for speech intensity regulation within this naturalistic context is yet to be explored and it is hypothesized that increased interlocutor distance will be associated with an increased slope of the AIF function.

1.3 Directed attention

Of additional interest is the question of what role the speaker’s level of attention to auditory feedback plays in the regulation of speech intensity. Specifically, if a speaker’s attention is directed to their auditory feedback, will the impact of altered feedback be increased or reduced. To our knowledge, only two studies have explored this condition. Siegel and Pick [1] found a similar slope of the function of AIF when participants were instructed to ignore the altered feedback in background noise ($.15$). Lane, Catania and Stevens [19] however, found a reduced slope when participants were asked to ignore altered feedback while producing a vowel (ah). Thus, the ability to maintain a constant intensity of speech while ignoring auditory feedback remains poorly understood.

2 Methods

2.1 Participants

Ten healthy female adults (aged 19-32 years) served as participants. All participants passed a bilateral 25 dB HL hearing screening at .25, .5, 1, 2 and 4 kHz. Participants spoke English as their primary language and had no history of speech, hearing or neurological impairments. The current study was approved by the Non-medical Research Ethics Board at Western University, London, Ontario, Canada. Informed consent was obtained from all participants.

Apparatus and acoustic measures

Participants were seated in an audiometric booth for the duration of the study. Participants were provided with a standard set of audiometric headphones (Telephonics 51OCO17-1) and headset microphone (AKG C520) attached to a preamplifier (M-Audio preamp USB), audiometer (GSI-10, model 1710), and desktop computer. The microphone was placed 6 cm from the midline of the participant's mouth. Calibration of the microphone was obtained with a sound level meter placed 15 cm (6 inches) from the participant's mouth while they produced three short (< 5sec) 'ah' sounds at 70 dBA SPL. The recording module in the Praat software [35] was used to digitize the speech samples at 44.1 kHz and 16 bits. During speech tasks, the audiometer was used to alter the intensity of the participant's speech. The headphone output was calibrated (made equivalent) to the input microphone using speech noise produced by the audiometer and an audio speaker placed 6 cm from the headset microphone. The calibration of the output of the headphones was accomplished with an earphone coupler (Bruel & Kjaer, type 4152) attached to a sound level meter (Bruel & Kjaer, type 2203). For the measurement of speech intensity in all conditions and tasks, the recorded speech audio files were analyzed off-line using the acoustic intensity measurement module in the Praat program [35]. The root mean squared (RMS) intensity contour method was used to obtain the average intensity for each utterance. Average speech intensity across 2-3 second segments of speech were used for this analysis, with long pauses (>500ms) removed.

2.2 Procedures

Participants were prompted by the experimenter to complete speech-related tasks in the following sequence: produce 1) a prolonged vowel sound (ah) in a comfortable speaking loudness, 2) engage in conversation with the experimenter at a close distance (1 meter), 3) engage in conversation a second time with the experimenter at a far distance (6 meters), 4) read sentences printed on paper, and 5) read sentences printed on paper while attempting to maintain their habitual speech intensity and ignore the AIF. A detailed description of each of the above tasks is presented in section 2.3.1. The order of tasks was selected to minimize the potential influence of some of the tasks on subsequent tasks. For example, the task involving the instruction to "ignore the altered feedback" was always given last because of concerns that it might influence

attention strategies used in subsequent conditions. Throughout each of the speech-related tasks listed above (1-5), the participants received randomly presented AIF related to their own speech. The random AIF conditions included 2 repetitions of the following 13 conditions; 2.5, 5, 7.5, 10, 12.5, and 15dB reductions in the feedback intensity and 0, 2.5, 5, 7.5, 10, 12.5, and 15dB increases in the feedback intensity. These conditions were selected because previous AIF literature focused primarily on 10dB increments and pilot data suggested that speech production responses are evident (participants were noted to produce speech responses in the opposite direction to the alteration) with smaller increments. Participants were naïve to the altered feedback conditions. AIF was initiated following instructions for each task, just prior to participant speech production and was terminated once the participant completed the requested task.

Speech tasks and conditions

Vowel Prolongation. Participants were required to produce a sustained phonation of "ah" in a comfortable speaking voice for approximately 3 seconds for each of the AIF conditions.

Conversation. Participants were requested to discuss familiar topics with the experimenter for about 5-10 utterances per altered feedback condition. Topics included family, hobbies, occupational experiences, interests, and recent vacations. The first conversational task was performed with the listener-experimenter at an interlocutor distance of 1 meter (near). The second conversational task occurred at an interlocutor distance of 6 meters (far).

Sentence Readings. Sentences included two randomly selected items from the Sentence Intelligibility Test (SIT) [36] as well as the sentence, "She saw patty buy two poppies". Participants first read aloud the sentences with no specific instruction regarding speech loudness except to "read these sentences to me". Following this task, they read aloud the sentences with the instruction to maintain a constant comfortable voice and try to ignore the altered feedback presented through the headphones.

2.3 Statistical analysis

Each participant's average speech intensity obtained for each of the 13 levels of AIF was analyzed using linear regression (value of altered feedback versus value of resulting speech intensity). The slope and zero intercept values, obtained from the participants' linear regressions during each of the 5 speech tasks, were submitted to six separate repeated measures analyses of variances (followed by post-hoc analyses and Bonferroni correction for multiple comparisons) in order to examine for differences in the mean slope and the mean intercept across 1) the three speech tasks (conversation at a near distance, vowel, reading with no instructions); 2) the two distance conditions (conversation at a near distance and conversation at a far distance); and 3) directed attention conditions (reading with no instruction and reading with instruction to ignore altered feedback). R2 values (coefficient of determination) from each participant's regression slopes were averaged and mean R2 are provided in Table I.

Table 1: Average Altered Intensity Feedback (AIF) slope, zero intercept, and R² values for the five speech tasks/conditions with standard deviations in parentheses.

Speech Task	AIF-related Slope Values (SD)	AIF-related Intercept Values (SD)	R ² values (SD)
Vowel production	-0.11 (0.03)	70.20 (4.24)	.52 (0.20)
Reading sentences (no instruction)	-0.07 (0.02)	67.07 (3.35)	.46 (0.12)
Reading sentences (instruction to ignore altered feedback)	-0.04 (0.04)	65.59 (2.11)	.23 (0.23)
Conversation near (1 meter interlocutor distance)	-0.16 (0.07)	66.28 (3.36)	.53 (0.22)
Conversation far (6 meters interlocutor distance)	-0.17 (0.05)	69.04 (3.04)	.67 (0.16)

3 Results

All participants responded to the AIF by producing speech intensity opposing the alteration. This finding was consistent across speech tasks. Results for speech intensity production are presented as linear regression slope values for all speech tasks in the boxplot in Figure 2

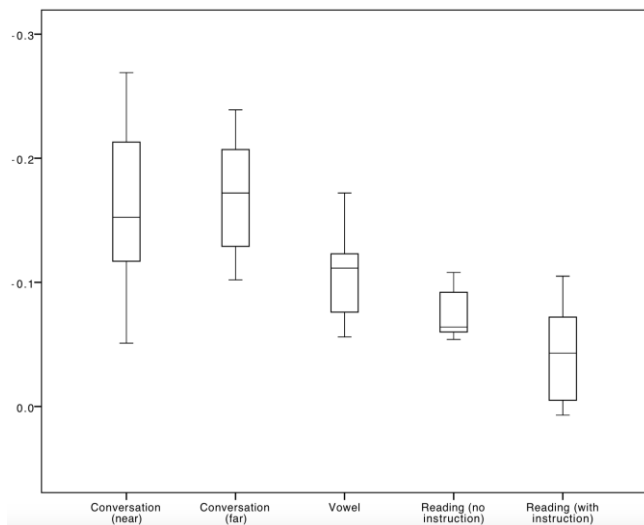


Figure 2: Average slope values for all tasks.

3.1 Slope

Speech tasks

Results for the RM-ANOVA indicated violation of sphericity ($p > .05$) and there was a significant effect of speech task on the AIF-related slope value using the Greenhouse-Geisser correction [$F(1.28, 11.52) = 14.311, p < .05$]. Pairwise

comparisons between the three speech tasks revealed a significantly reduced slope (flatter) for the reading task ($M = -0.07, SD = 0.02$) compared to the conversation task ($M = -0.16, SD = 0.07; p < .05$). Individual and group mean results presented as linear regression slope functions for the speech tasks are depicted in Figure 3.

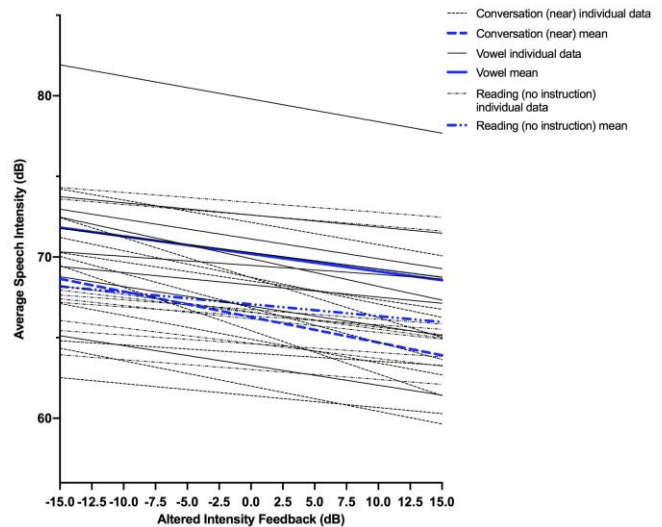


Figure 3: Individual and group regression slopes for the Speech Tasks (conversation near distance, vowel, reading no instruction).

Distance conditions

Results for the RM-ANOVA indicated there was no significant difference in the slope values for the conversation at an interlocutor distance of one meter versus six meters [$F(1,9) = .32, p = .59$]. Results for the distance conditions are depicted in Figure 4.

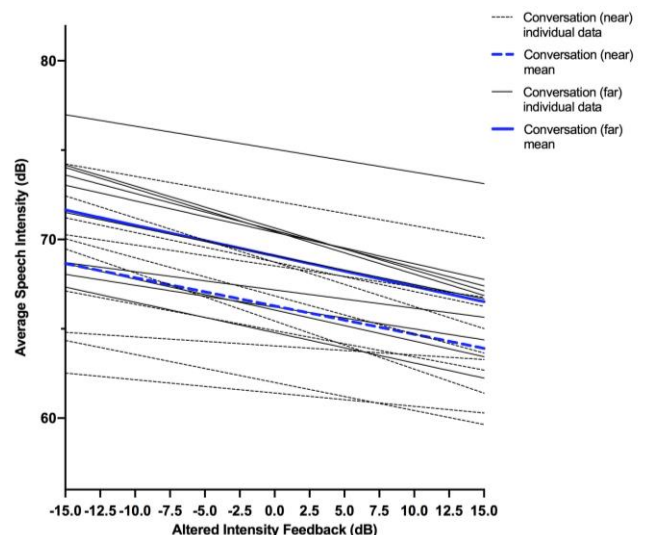


Figure 4: Individual and group regression slopes for the Distance Tasks (conversation at a near and conversation at a far distance).

Directed attention

Results for the RM-ANOVA indicated there was no significant difference in the slope values for the reading without instruction task versus reading with instruction task

[F (1,9) = 4.20, p = .07]. Results for the reading conditions are depicted in Figure 5.

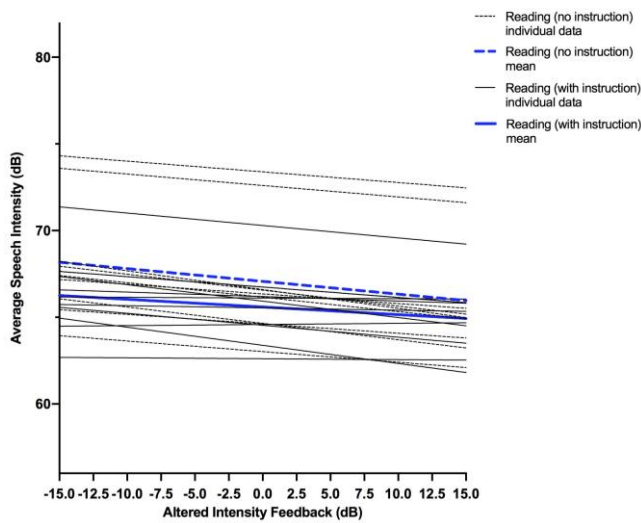


Figure 5: Individual and group regression slopes for the Directed Attention Tasks (reading with and without instruction).

3.2 Zero intercept

Speech tasks

RM-ANOVA analysis found a significant effect of speech task on the AIF-related intercept value [F (2,18) = 9.49, p < .05]. Pairwise comparisons between the three speech tasks revealed a lower intercept for the conversation at a near distance task (M = 66.28, SD = 3.36 dB) compared to the vowel task (M = 70.20, SD = 4.24 dB; p < .05). The zero intercept results from all tasks and conditions is depicted in Figure 6.

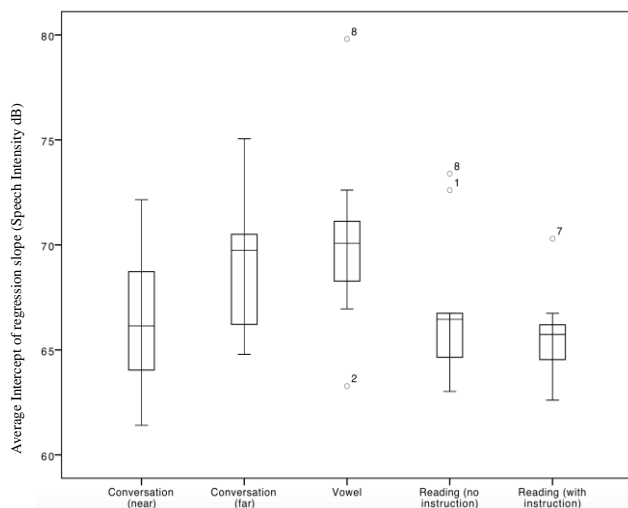


Figure 6: Average intercept for all tasks.

Distance conditions

RM-ANOVA analysis found a significant effect of speaking distance on the AIF-related intercept value [F (1,9) = 78.90, p < .001] related to an increased intercept in the conversation far task (M = 69.04, SD = 3.04 dB) compared to the conversation near task (M = 66.28, SD = 3.36 dB).

Directed attention

Results for the RM-ANOVA indicated that although slightly increased, there was no significant difference in the intercept values for the reading without instruction and the reading with instruction to ignore altered feedback task [F (1,9) = 1.23, p = .30].

4 Discussion

The goal of the present study was to determine the role of AIF on speech intensity regulation in the context of several speech tasks and conditions. Overall, participants in the current study modified their speech intensity in a compensatory manner (opposing direction) based on the auditory feedback intensity presented. This finding is consistent with previous literature [1, 18-21], and confirms that auditory feedback plays a role in the regulation of speech intensity. A novel aspect of the current study was the finding that the speech task and speech condition can affect the compensatory response to AIF. We found a reduced slope of the altered feedback function with the reading task compared to the conversation task. Possible explanations for this finding are discussed in “Speech tasks” below. These results are consistent with and also extend the findings of previous research [26, 27] as the present study found these results to be maintained in no-noise conditions.

The average intercept of the regression function when producing a vowel was greater compared to speaking in conversation. One previous study found a similar increase in speech intensity for vowel production tasks compared to sentence reading and speaking extemporaneously [37].

The present study explored the impact of AIF in different speaking conditions (i.e. different interlocutor distances). Consistent with previous literature [29, 30] we found an increase in speech intensity with increasing interlocutor distance. However, the current study expands on these findings as the increase in speech intensity with increased interlocutor distance was observed in the context of AIF. In contrast, we did not find a difference in average slope across the different interlocutor distances, which presents opportunities for future research.

Previous research has identified gender-related differences in speech intensity such that men produce higher speech intensity in both reading and vowel prolongations [37] and Healey and colleagues [31] found that women produce larger increases in intensity across interlocutor distances. The current study was limited to female participants and therefore generalizations are cautioned.

Another speaking condition that should be considered in the AIF context is speaking in background noise, as speakers regulate their speech intensity in noise so as to maintain an adequate speech-to-noise ratio [38]. Previous work by Lane and Tranel [38] and Siegel and Pick [1] suggest that the addition of background noise to altered feedback conditions intensifies the response of the AIF effect. Future studies should explore the role of auditory feedback for speech intensity regulation in the context of background noise while completing a variety of speech tasks.

Another goal of the present study was to examine the effect of instructions related to focus of attention on the AIF response functions. No difference was found between the reading task with instructions to ignore the altered feedback and the reading task without these instructions. Although there was a reduced slope in the reading task with instruction to ignore feedback, this did not reach significance. Siegel & Pick [1] found a similar slope of the function when asked to read sentences in background noise with and without instructions to ignore altered feedback. However, we found this in the absence of background noise suggesting the robustness of this finding.

Speech tasks

Results from the current study suggest that when producing a quasi-speech task, such as reading sentences, use of auditory feedback differs compared to when producing more naturalistic speech such as speaking in conversation. It is proposed that this may be related to two important influences: the complexity of the task, and differences in the communicative demands. With regard to complexity, the motor skill required and the attention/cognitive demands are considered distinct based on whether the speaker is executing a speech or quasi-speech task [39, 40]. Specifically, the complexity of the speech task relates to the degree of automaticity. Sentence reading tasks are considered to be more automatic and reduced in complexity compared to less automatic conversation tasks [41, 42]. For example, the speakers' loudness, pitch, articulation, vocal quality, and prosodic patterns may be engaged in order to be better understood during a conversational task. In addition, despite word-level complexity being comparative across these tasks, word selection is a process that only occurs during spontaneous conversational speaking tasks. Finally, additional processing of cues such as listener understanding and communication breakdown monitoring may be occurring during conversation tasks (when speaker and listener are engaged in turn-taking), however reading tasks may not engage these types of cognitive/attentional monitoring-type behaviours. It has been suggested that more automatic skeleto-motor movements are less impacted by distorted feedback than non-automatic movements [43]. This is an important consideration in the context of current theories of sensorimotor feedback and feedforward mechanisms, which posit that altered feedback, such as that created when speaking in background noise (Lombard effect) influences speech production in a seemingly rapid and involuntary manner [44, 45]. This has led to speech regulation mechanisms conceptualized as involving sensorimotor feedback loops that alter and update feedforward models of the intended speech output [44, 45]. A reduced slope during the reading task in the current study is suggestive of a relatively reduced impact of altered feedback. It is plausible that when executing a less complex and thus more automatic speech task, we require less input from ongoing sensory monitoring processes (sensorimotor feedback) because our speech intensity regulation system (internal model) considers speech intensity outputs from these tasks more reliable. In

contrast, spontaneous speech may be considered comparatively increased in complexity, as this requires an internally generated motor plan, which is initiated and executed with the additional requirements of continuous self-monitoring during the movement.

Complexity of speech and quasi-speech tasks are also reflected in differences in underlying neuroanatomical patterns of control [40; refer to 39 for a review]. For example, unilateral left motor cortex lateralization has been observed in some imaging studies during speech tasks versus bilateral activation during non-speech oral tasks [46]. There is some evidence to suggest that altered feedback (frequency shifted) is associated with increased activity in the right hemisphere compared to unaltered feedback [47]. One possible hypothesis is that the right hemispheric activation during altered feedback requires complex integration processing of both hemispheres during conversational tasks, which typically only require unilateral pathways in unaltered feedback. Therefore, the sensorimotor integration of speech may involve distinct pathways and it is possible that fundamental differences in complexity of the neural control of speech during AIF may explain the relative slope differences found in the current study between speech and quasi-speech reading task. However, it is important to note that although the vowel task is typically considered a quasi-speech task, the current study did not find a significant difference between the vowel task and the conversation task. The differences between different quasi-speech tasks and the neural control of speech intensity during AIF across speech tasks requires further research.

Observed slope differences may be associated with differences in the communicative demands of the speech tasks. When a speaker is attempting to communicate a message, there is motivation and attention directed towards producing and maintaining adequate speech intensity to avoid reductions in speech intelligibility or communicative errors. Healthy speakers prioritize intelligibility, as evidenced by modifications of the speech signal when intelligibility is at risk of being compromised. One such modification is increasing speech intensity when speaking in noisy conditions despite this modification requiring a perceived increase in effort [23, 48, 49].

Related to motivational goals of communicating, previous literature suggests that certain tasks may prompt the speaker to maximize communication efficiency [50]. As such, with a presumed communication goal of increased intelligibility while speaking to a listener, we should expect a higher loudness-to-efficiency ratio, compared to a lower efficiency-to-loudness ratio during reading; when the goal that a listener perceive accurate information is comparatively reduced. Subsequently, to accomplish this goal, the speaker presumably relies on increased attention when in conversation. The net effect of increased motivation and attention, results in larger compensatory responses to altered feedback in conversation. In the current study, participants displayed larger compensatory responses to the AIF for the speech tasks with greater communicative demands (i.e. conversation) than speech tasks with lower communicative demands (reading sentences), consistent with the

communication demands hypothesis. This potentially important effect of the communicative demands on the response to altered feedback may be relatively independent of other factors or demands that typically produce large changes in speech intensity (i.e. interlocutor distance).

The content of the message may play a role in intensity adjustments. This includes communicative intent and emotional content; high emotional content may involve different neural control processes (direct corticobulbar pathways) [51] and produce wide ranges of speech loudness, which may not exist in emotionally neutral conversation. Methods to control for conversational or monologue content were employed in the current study. Conversation was elicited in the most natural manner possible, and therefore at times the topic shifted from the initial questions. Instances of noticeably high emotionally laden utterances during which the participant was visibly upset, were excluded from analysis (e.g. discussions that naturally progressed to death of a loved one). In these rare instances, additional samples of speech for that altered intensity feedback condition were elicited and were used to replace the emotionally laden utterances. Conversation included in all analysis were limited to emotionally neutral discussions such as describing a most recent vacation. However, it is possible that despite these precautions, some conversational samples may have involved high emotion content without the experimenter being aware. Future studies should consider using supplemental questions to verify emotional content of conversation.

Distance conditions

Talker-to-listener distance, or interlocutor distance explores a speaking condition that requires regulation of intensity based on multiple sensory processes. These include visual processing (e.g. depth perception) and auditory processing (e.g. self-produced speech as well as externally generated speech from the conversational partner). To our knowledge, the current study is the first to explore the relationship between interlocutor distance conditions and AIF. The results confirm that a similar slope function is observed during a conversation task regardless of interlocutor distance. Based on the communicative demands hypothesis, an increased slope function was expected with increasing distance between speaker and listener, since this would require improved monitoring of speech intensity regulation for avoidance of reduced intelligibility. The current results suggest that perhaps there is a ceiling beyond which increased attention towards sensorimotor feedback fails to alter the response. It is possible that the increased intercept (overall increase in speech intensity) in the far interlocutor distance condition provided adequate maintenance of speech intelligibility thereby rendering any further adjustments to the slope response unnecessary. The results also strengthen the evidence that the nature of the speech task plays an important role in intensity-related auditory-motor performance.

Directed attention

Overall, the data suggests that during the conditions of the present study, healthy speakers have difficulty ignoring the altered auditory feedback signal when given this explicit instruction. In other words, it appears that auditory feedback mechanisms were quite robust and the speakers appeared to be unable to use alternate mechanisms to control the level of their compensation. This finding should be interpreted with caution as we found a reduced R2 in this task suggesting a possible non-linear pattern in the equation. This is possible if the ability to ignore the altered feedback signal is related to the direction of the alteration, for example if it is easier to ignore the altered feedback when the feedback is in the negative direction than in the positive direction. Perhaps speakers are more sensitive to increased loudness as this relates to discomfort which may be more difficult to ignore compared to reduced loudness which may not be related to discomfort and is therefore easier to ignore. It is also possible that the lower R2 may be related to increased intra subject variability, such that there were trial-to-trial differences in the participant's ability to ignore the altered feedback.

The ability to direct attention towards and away from the intensity feedback of one's own voice, as well as the act to suppress the AIF compensation response requires further examination as inconsistencies appear in the literature. Lane and colleagues [19] found a reduced slope when instructed to ignore auditory feedback. It is important to note that in the current study, the slope in the reading task (with no instructions) was low, and therefore the non-significant difference when reading with instruction to ignore feedback is related to a possible floor effect. In the Lane and colleagues study [19], the non-ignore task had a much higher slope of -0.46 in the context of a sustained vowel, providing further support for this possible rationale. Future studies should examine the ignore feedback condition in the context of speech tasks with higher slope values, such as vowel prolongation or conversation tasks.

Related to this, evidence from previous studies by Scheerer and colleagues [52] and Tumber and colleagues [53] suggest that attention plays an important role in speech during altered feedback (note these were frequency perturbations) such that reduced compensations to distorted feedback were observed when subjects' attentional load was divided (speech combined with a visual distraction dual task). The "ignore altered feedback" condition in the current study may be creating a similar dual task manipulation such that the participants were required to read sentences while directing attention to the sound of their voice. This division of attention may have attenuated the response to the altered feedback in this condition, however this requires further examination in future studies.

5 Conclusion

The results of the present study confirm that auditory feedback about intensity plays an important role in the regulation of speech intensity in healthy speakers. Specifically, we found the role of auditory information for intensity regulation to be particularly important during

specific speech tasks requiring complex processing and explicit communication goals. We found an increased response (steeper function) across a range of AIF levels in speaking conditions that require a clear communicative function such as having a conversation with a communication partner. This increased response function contrasted with the reduced response function observed in speech tasks without a communicative function (when reading sentences). These results suggest that the communication goal or the demands of the speech task may interact with auditory feedback to significantly influence the regulation of speech intensity. Although the use of auditory feedback for speech intensity regulation may be salient and in the current study healthy speakers had difficulty ignoring the altered auditory feedback when explicitly asked to do so, future studies are required to examine this finding in more detail. The current study aimed to provide a starting point from which to understand the effects of auditory feedback in healthy speakers however, future studies would benefit from examination of AIF during a range of speaking tasks in a larger sample size. Additional directions for future research include comparison to healthy older adults, as some researchers have suggested heightened sensitivity to sensory feedback in this cohort [54] as well as neurologically impaired populations with specific deficits related to speech loudness control. The current study was limited to native English-speakers and generalization to other populations is to be avoided.

Finally, the AIF paradigm is distinct from perturbation paradigms since brief perturbation shifts in the speech signal may involve involuntary processes. This is in contrast to AIF which may be under more voluntary control as the auditory alterations may be more perceptible to the speaker. Related to this, the current study did not examine possible sensorimotor adaptation processes, which is typically examined in the context of auditory perturbations. Adaptation is defined as involving “after-effects” such that the change in behaviour (compensation to altered perturbation) is continued after the altered feedback is removed (reducing or increasing the following response) [12, 55-58]. The current study did not examine potential after-effects of AIF, and instead the analyzed speech samples were selected from the mid-sections of vowel and utterance productions. It is presumed that if adaptation processes were occurring in the current study, an unpredictable pattern of findings across altered feedback conditions (non-linear function) may have been observed. However, in the current study, a steep slope of the function in the conversation task was observed, which means that following a change in the altered feedback condition, there was a predictable and stable pattern. Still, the dynamic adaptation processes that may be occurring in AIF is an interesting area of future research. Further directions for future research include examination of the distinction between AIF and perturbation experimental paradigms and the theoretical underpinnings.

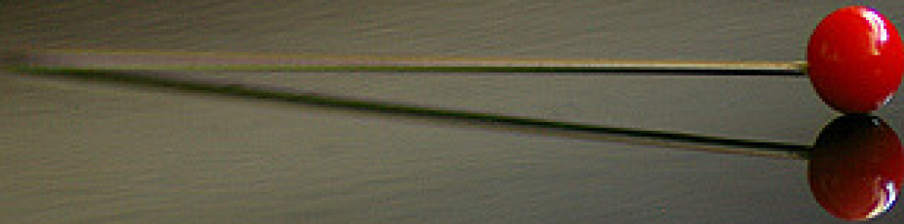
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Sherbrooke (Québec) October 6-8,
2021



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You are invited to be part of this three-day conference featuring the latest developments in Canadian acoustics and vibration. Sherbrooke is well known in acoustics for the Groupe d'Acoustique de l'Université de Sherbrooke (GAUS) founded in 1984.

The conference will be an excellent opportunity to visit or rediscover the GAUS during the International Year of Sound!

The keynote talks and technical sessions will be framed by a welcome reception, conference banquet, Acoustical Standards Committee meeting, technical tour and an exhibition of products and services related to the field of acoustics and vibration.

Take a few days before or after the conference to enjoy the area and the cultural activities! Especially have a look to the beautiful surrounding nature during Fall colors with Mont-Bellevue downtown and the nearby 'Mont-Orford' National Park. Three other parks can also be found within a radius of 100 km.

Various demos and activities will be held at the Groupe d'Acoustique de l'Université de Sherbrooke (GAUS) and at Université de Sherbrooke campus - A series of innovative workshop activities will be a part of the program; we are open to proposals along this line (challenges, measurements, simulations).

Venue and Accommodation – The conference will be held at the Hotel Delta by Marriott in Sherbrooke. A block of rooms in the hotel will be available at a special rate. Complimentary city bus passes will be offered to all the participants to promote the use of public transport during the conference. A shuttle is also available to provide a direct link between International Montréal Trudeau Airport and the conference venue. Please refer to the conference website for further details and registration: <https://awc.caa-aca.ca/index.php/AWC/AWC21>

Plenary, Technical and Workshop Sessions are planned throughout the conference. Each day will begin with a keynote talk of broader interest and relevance to the acoustics community. Technical sessions are planned to cover all areas of acoustics including:

AEROACOUSTICS / ARCHITECTURAL AND BUILDING ACOUSTICS / BIO-ACOUSTICS AND BIOMEDICAL ACOUSTICS / MUSICAL ACOUSTICS / NOISE AND NOISE CONTROL / PHYSICAL ACOUSTICS / PSYCHO- AND PHYSIO-ACOUSTICS / SHOCK AND VIBRATION / SIGNAL PROCESSING / SPEECH SCIENCES AND HEARING SCIENCES / STANDARDS AND GUIDELINES IN ACOUSTICS / ULTRASONICS / UNDERWATER ACOUSTICS

A General Public Session is currently planned on the afternoon of the last conference's day and linked to the International Year of Sound 2020-2021, a global initiative to highlight the importance of sound and related sciences and technologies for all in society (<https://sound2020.org/>). This event will be held on Université de Sherbrooke campus and opened to scholars and to the population. The organizing committee welcomes any proposal for this session, a rare occasion of explaining our everyday job and implications for society.

Exhibition and Sponsorship – The conference offers opportunities for suppliers of products and services to engage the acoustic community through exhibition and sponsorship.

The tabletop exhibition facilitates in-person and hands-on interaction between suppliers and interested individuals. Companies and organizations that are interested in participating in the exhibition should contact the Exhibition and Sponsorship coordinator for an information package. Exhibitors are encouraged to book early for best selection.



Anechoic room and wind-tunnel opening at GAUS

The conference will be offering sponsorship opportunities of various conference features. In addition to the platinum, gold and silver levels, selected technical sessions, social events and coffee breaks will be available for sponsorship. Additional features and benefits of sponsorship can be obtained from the Exhibition and Sponsorship coordinator and on the conference website. Demos can also be organized at Groupe d'Acoustique de l'Université de Sherbrooke.

Students are strongly encouraged to participate. Students presenting papers will be eligible for one of three Best Presentation Student prizes to be awarded. Conference travel bursaries will also be available to those students whose papers are accepted for presentation.

For Registration details, please refer to the conference web site <https://awc.caa-aca.ca/index.php/AWC/AWC21>

Contacts

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(Olivier.Robin@USherbrooke.ca)

Technical co-Chairs:
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Sebastian Ghinet
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(Sebastian.Ghinet@nrc-cnrc.gc.ca)

Exhibits and Sponsorships:
Julien Biboud
(Julien.Biboud@mecanum.com)



Enjoy the Mont Bellevue in the center of Sherbrooke during Fall

Annonce

SEMAINE CANADIENNE D'ACOUSTIQUE



Sherbrooke (Québec) 6-8 Octobre 2021



Vue du Mont-Orford depuis le centre-ville de Sherbrooke

Suite à son report en 2020, la Semaine canadienne d'acoustique 2021 se tiendra du 06 au 08 octobre 2021 à Sherbrooke, Québec.

Nous vous invitons à prendre part à cette conférence de trois jours sur les derniers développements en matière d'acoustique et de vibrations au Canada. Sherbrooke est reconnue en acoustique pour le Groupe d'Acoustique de l'Université de Sherbrooke (GAUS) fondé en 1984.

La conférence sera le moment idéal pour visiter ou redécouvrir le GAUS durant l'année internationale du son !

Les exposés principaux et les séances techniques seront encadrés par une réception de bienvenue, un banquet, une réunion du comité des normes acoustiques, une visite technique et une exposition de produits et services liés au domaine de l'acoustique et des vibrations.

Prenez quelques jours avant ou après la conférence pour profiter de la région et des activités culturelles ! Découvrez la nature environnante durant la flambée des couleurs d'automne, avec la proximité du Parc National du Mont-Orford. Trois autres parcs nationaux sont accessibles dans un rayon de 100 km.

Diverses démonstrations et activités seront organisées au sein du Groupe d'Acoustique de l'Université de Sherbrooke (GAUS) et sur le campus principal de l'université de Sherbrooke. Des ateliers participatifs seront intégrés dans le programme; nous sommes ouverts à toute proposition (concours, mesures, simulations).

Lieu et hébergement – La conférence aura lieu au Centre de congrès de l'Hôtel Delta Sherbrooke. Un bloc de chambres dans l'hôtel sera disponible à un tarif spécial. Des passes de bus seront offertes à tous les participants afin de favoriser l'usage du transport en commun durant la conférence. Une navette directe entre l'aéroport international Trudeau de Montréal et le lieu de la conférence est également accessible sur demande. Veuillez consulter le site Web de la conférence pour plus de détails et pour l'inscription: <http://awc.caa-aca.ca/AWC/AWC21>

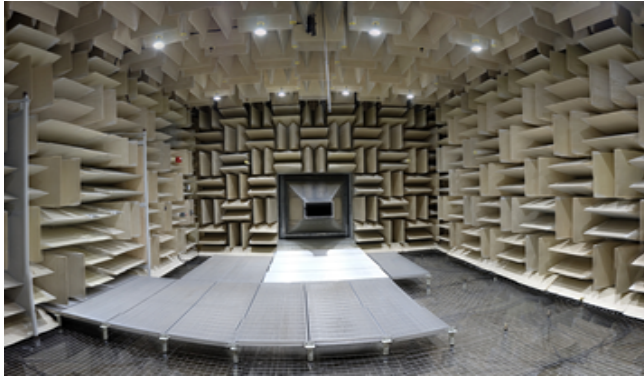
Des séances plénières, techniques et des ateliers sont prévus tout au long de la conférence. Chaque journée débutera par une plénière d'un intérêt et d'une pertinence plus larges pour la communauté de l'acoustique. Des sessions techniques sont prévues pour couvrir tous les domaines de l'acoustique, y compris

AÉROACOUSTIQUE / ACOUSTIQUE DU BÂTIMENT ET ARCHITECTURALE / BIOACOUSTIQUE / ACOUSTIQUE BIOMÉDICALE / ACOUSTIQUE MUSICALE / BRUIT ET CONTRÔLE DU BRUIT / ACOUSTIQUE PHYSIQUE / PSYCHOACOUSTIQUE / CHOCS ET VIBRATION / LINGUISTIQUE / AUDIOLOGIE / ULTRASONS / ACOUSTIQUE SOUS-MARINE / NORMES EN ACOUSTIQUE

Une session grand public est planifiée en après-midi du dernier jour de la conférence, et liée à l'année internationale du son 2020-2021, une initiative globale destinée à illustrer l'importance du son et de ses sciences et technologies dans la société (<https://sound2020.org/>). Cet événement se déroulera sur le campus de l'Université de Sherbrooke et sera ouvert aux scolaires et à la population. Le comité organisateur est ouvert à toute proposition pour cette session, une rare occasion d'expliquer notre travail et ses implications pour la société.

Exposition et Parrainage - La conférence offre aux fournisseurs de produits et de services la possibilité de faire participer la communauté acoustique par l'exposition et le parrainage.

L'exposition sur le plateau facilite l'interaction en personne des fournisseurs et des personnes intéressées. Les entreprises et organisations désirant participer à l'exposition doivent contacter le coordonnateur de l'exposition et du parrainage pour obtenir un dossier d'information. Les exposants sont encouragés à réserver tôt pour obtenir de meilleures opportunités.



Salle anéchoïque et soufflerie au GAUS

La conférence offrira des possibilités de parrainage de divers événements de la conférence. Outre les niveaux platine, or et argent, des séances techniques, des événements sociaux et des pauses café seront disponibles pour le parrainage. Les commanditaires peuvent placer leur logo sur le site Web de la conférence dans les 10 jours suivant leur parrainage. Les caractéristiques et avantages supplémentaires du parrainage peuvent être obtenus auprès du coordonnateur des expositions et des commandites ou sur le site Web de la conférence.

Les étudiants sont fortement encouragés à participer. Les étudiants qui présenteront seront admissibles à l'un des trois prix pour les meilleures présentations. Des subventions de voyage seront également offertes aux étudiants dont les communications sont acceptées pour présentation.

Pour plus d'informations sur l'inscription, veuillez consulter le site Web de la conférence : <http://awc.caa-aca.ca/AWC/AWC21>.

Contacts

Président de la conférence :

Olivier Robin

(Olivier.Robin@USherbrooke.ca)

Présidents techniques :

Patrice Masson and

Sebastian Ghinet

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(Sebastian.Ghinet@nrc-cnrc.gc.ca)

Exposants et commandites :

Julien Biboud

(Julien.Biboud@mecanum.com)



Appréciez le Mont Bellevue au centre de Sherbrooke durant l'automne

CANADIAN ACOUSTICS TELEGRAM ANNOUNCEMENTS - ANNONCES TÉLÉGRAPHIQUES DE L'ACOUSTIQUE CANADIENNE

Looking for a job in Acoustics?

There are many job offers listed on the website of the Canadian Acoustical Association!

You can see them online, under <http://www.caa-aca.ca/jobs/>

August 5th 2015

Acoustics Week in Canada 2020

Because of the COVID-19 situation, the Acoustics Week in Canada (AWC) originally planned for October 2020 in Sherbrooke (QC) will be postpone to October 2021. Nevertheless, and as a "warm up", Sherbrooke's organising committee is currently looking into setting up a little 1-day online celebration for October 2020. You can find more information on the AWC20 and AWC21 websites. Please note that St-John's (NL) will host the AWC2022 conference.

May 3rd 2019

Acoustics Week in Canada 2021

Because of the COVID-19 situation, the Acoustics Week in Canada (AWC) originally planned for October 2020 in Sherbrooke (QC) will be postpone to October 2021. Nevertheless, and as a "warm up", Sherbrooke's organising committee is currently looking into setting up a little 1-day online celebration for October 2020. You can find more information on the AWC20 and AWC21 websites. Please note that St-John's (NL) will host the AWC2022 conference.

May 3rd 2019

2020: International Year of Sound

The International Year of Sound (IYS 2020) is a global initiative to highlight the importance of sound in all aspects of life on earth and will lead towards an understanding of sound-related issues at the national and international level.

Inspired by the achievements of La Semaine du Son (The Week of Sound), and following naturally as an important contribution to UNESCO Resolution 39 C/49 25 September 2017 on "The Importance of Sound in Today's World: Promoting Best Practices", the International Commission for Acoustics (ICA) is mobilizing its Member Societies and International Affiliates to promote best practices in sound during the year of 2020 to create an International Year of Sound (IYS 2020). For more info, visit <http://sound2020.org/>

May 3rd 2019

COVID-19 Situation

Because of the COVID-19 situation, the Acoustics Week in Canada (AWC) originally planned for October 2020 in Sherbrooke (QC) will be postpone to October 2021. Nevertheless, and as a "warm up", Sherbrooke's organising committee is currently looking into setting up a little 1-day online celebration for October 2020. You can find more information on the AWC20 and AWC21 websites. Please note that St-John's (NL) will host the AWC2022 conference.

May 13th 2020

AWC2020 - One day online celebration of acoustics in Canada

Because of the COVID-19 situation, the Acoustics Week in Canada (AWC) originally planned for October 2020 in Sherbrooke (QC) will be postpone to AWC21 in October 2021. Nevertheless, CAA-ACA with Sherbrooke's organising committee has decided to set up a 1-day celebration on October 9, 2020. All details are available on

AWC2020 conference website.

Dear members and friends of the CAA, Because of the COVID-19 situation, the Acoustics Week in Canada (AWC) originally planned for October 2020 in Sherbrooke (QC) will be postpone to AWC21 in October 2021. Nevertheless, CAA-ACA with Sherbrooke's organising committee has decided to set up a 1-day celebration on October 9, 2020 (see detailed schedule on AWC2020 conference website). This online event represents a unique opportunity for students to present (live or pre-recorded) their work in a Pecha-Kucha style, and have a chance to win one of three Best Student Presentation awards. Several break-out sessions will also be organized around the usual themes according to submitted abstracts. Others sessions include an "Acoustical Gems" luncheon (alluring educational resources, laboratory demonstrations or research results), one plenary session and a session dedicated to the COVID-19 pandemic associated impacts, challenges and opportunities for the CAA-ACA community. The addition of the award ceremony and a recorded concert will make this a full day! To present during this free online event, reserved to CAA registered members, all presenters are invited to submit a 200-words abstract by July 31st directly from AWC2020 conference website. The list of accepted abstracts will be published in the September issue of Canadian Acoustics journal, and the recorded content might be promoted on the Canadian Acoustical Social media. Check out our journal, website, and follow us on LinkedIn and Twitter

July 11th 2020

À la recherche d'un emploi en acoustique ?

De nombreuses offre d'emploi sont affichées sur le site de l'Association canadienne d'acoustique !

Vous pouvez les consulter en ligne à l'adresse <http://www.caa-aca.ca/jobs/>

August 5th 2015

Semaine canadienne de l'acoustique 2020

En raison de la situation COVID-19, la Semaine canadienne de l'acoustique (AWC) initialement prévue en octobre 2020 à Sherbrooke (QC) sera reportée à octobre 2021. Néanmoins, et comme "échauffement", le comité organisateur de Sherbrooke étudie actuellement la possibilité de mettre en place une petite célébration d'une journée en ligne pour octobre 2020. Vous pouvez trouver plus d'informations sur le site des conférences AWC20 et AWC21. Veuillez noter que St-John's (NL) sera l'hôte de la conférence AWC2022.

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May 3rd 2019

Situation COVID-19

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May 13th 2020

Why publish in Canadian Acoustics?



ISSN 0711-6659
canadian acoustics
acoustique canadienne
Journal de l'Association Canadienne d'Acoustique
SEPTEMBRE 2020
Volume ... - Numéro ...

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- Une alternative intéressante pour une évaluation par les pairs, fournissant aux auteurs des commentaires pertinents, objectifs et constructifs

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CAA membership is open to all individuals who have an interest in acoustics. Annual dues total \$120.00 for individual members and \$50.00 for student members. This includes a subscription to *Canadian Acoustics*, the journal of the Association, which is published 4 times/year, and voting privileges at the Annual General Meeting.

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**Executive Secretary, Canadian Acoustical:
Dr. Roberto Racca
c/o JASCO Applied Sciences
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L'adhésion à l'ACA est ouverte à tous ceux qui s'intéressent à l'acoustique. La cotisation annuelle est de 120.00\$ pour les membres individuels, et de 50.00\$ pour les étudiants. Tous les membres reçoivent *L'Acoustique Canadienne*, la revue de l'association.

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Les abonnements pour la revue *Acoustique Canadienne* sont disponibles pour les compagnies et autres établissements au coût annuel de 120.00\$. Des compagnies et établissements préfèrent souvent la cotisation de membre bienfaiteur, de 475.00\$ par année, pour assister financièrement l'ACA. La liste des membres bienfaiteurs est publiée dans chaque issue de la revue *Acoustique Canadienne*.

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