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Acoustique canadienne est publié quantre 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 exposées 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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Message du président
President's Message

Plexiglas & COVID-19 : arrêtez de construire des murs !

L‘année écoulée restera certainement dans les mémoires comme une année difficile pour tous, et certainement une année avec un paysage sonore très différent, surtout dans les villes, pour beaucoup des oreilles attentives des lecteurs de la revue Acoustique canadienne et des membres de l'Association acoustique canadienne. Sur ce point, j'aimerais saisir l'opportunité offerte par cette note éditoriale pour partager certaines de mes préoccupations concernant l'utilisation abusive du plexiglas dans nos vies COVIDées. Laissez-moi résumer : j'aime le plexiglas. Je l'ai découvert pendant mon adolescence et je l'ai immédiatement adopté pour tous mes montages et bricolages électroniques afin de leur donner un aspect professionnel et soigné (en fait, j'ai appris le truc du “polissage avec du talc pour bébé” il y a longtemps et je ne l'ai jamais oublié pour ressusciter un panneau de plexiglas rayé !). Cela étant dit, j'ai maintenant clairement le sentiment que le plexiglas est utilisé à tort en pleine pandémie actuelle de COVID-19 pour nous isoler (à l'épicerie, à la poste, etc.) et limiter la propagation des aérosols et des charges virales aéroportées. Les panneaux en acrylique transparent (communément appelé plexiglas) sont denses et rigides, et constituent donc également des barrières sonores très efficaces. Je ne suis probablement pas le seul à avoir déjà constaté l'énorme handicap créé par ces barrières de plexiglas suspendues ou autoportantes qui rendent toute communication verbale beaucoup plus difficile, voire impossible (sans parler du fait évident qu'un masque facial empêche déjà toute co-modalité de lecture labiale). J'ai vu beaucoup de jeunes caissières et caissiers (avec une audition probablement normale) avoir d'énormes difficultés à comprendre la question d'un client et finalement dégager - d'une manière ou d'une autre - le panneau d'isolement de leur chemin... avec tout le risque de contamination associé ! Inutile de mentionner non plus comment cette crise sanitaire a touché plus difficilement les personnes âgées qui sont aujourd'hui encore plus isolées en raison de leur audition vieillissante et de cette couche supplémentaire d'isolation sonore inutile (parfois au-dessus du masque ou couvre-visage qui atténue déjà les fréquences de la parole !). Et je dis inutile parce que je le pense : c'est une mauvaise conception mais qui semble avoir été largement adoptée néanmoins, peut-être pour sa simplicité, mais certainement pas pour son prix abordable!

Plexiglas & COVID-19: stop building walls!

This past year will certainly be remembered as a tough one for all of us, and one with a very different soundscape, especially in city centres, as many attentive ears such as those of our readers of Canadian Acoustics and members of the Canadian Acoustical Association can attest. Speaking of soundscape, I’d like to seize the opportunity offered by this editorial to share some of my concerns regarding the abusive use of plexiglass in our COVIDized lives. Let me be clear: I love plexiglass. I discovered it in my teenage years and immediately adopted it for all my DIY electronic kits to achieve that pro and polished look (having learned the “polish with talcum powder” trick to restore a scratched plexiglass panel!). That being said, I strongly feel that plexiglass is being wrongly used in the midst of the current COVID-19 pandemic as a physical barrier (grocery store check-out, post-office counter, etc.) to limit the propagation of aerosols and airborne viral loads. Clear acrylic panels (colloquially referred to as plexiglass) are dense and rigid, hence, they are extremely effective sound barriers. I’m probably not the only one to have witnessed the huge impairment created by these hanging or self-supporting plexiglass barriers that are making all verbal communication much harder, sometimes impossible (not to mention that a face mask already prevents all lip-reading co-modalities!). I’ve seen many young (hence probably normal-hearing) cashiers have a really difficult time understanding a patron’s question and ending up moving around or aside -one way or the other- the isolating panel... regardless of the risk of contamination! Not to mention how this sanitary crisis has had a great impact on the elderly who are not only affected because of their aging hearing, but by this extra layer of unnecessary sound isolation (added to the face mask, which already dampens speech frequencies!). And I say unnecessary because I mean just that: it is a bad design that is nonetheless widely adopted, maybe for it simplicity, but certainly not for its affordability. There must surely be ways to completely block airflow exchange without attenuating speech. A light rigid frame (wood, plastic, aluminum, etc.) supporting a plastic film (such as cellophane or for those who, like me, have the privilege of living in a cold climate and have heard of the heat shrinkable insulating film for indoor windows) would be just as efficient and most probably as easy to install and not

Il y aurait certainement des moyens de bloquer complètement l'échange de flux d'air tout en laissant la parole intacte. Un cadre léger et rigide (bois, plastique, aluminium, etc.) supportant un film plastique (pensez à votre film d'emballage alimentaire ou au film isolant thermorétractable des kits d'isolation des fenêtres intérieures pour les chanceux qui savent ce qu'est l'hiver) serait aussi efficace et probablement aussi facile à installer et pas plus difficile à nettoyer et à assainir, mais avec 2 avantages évidents : une barrière à base de film plastique serait complètement transparente visuellement et... acoustiquement. Pourquoi une telle installation n'est-elle pas plus répandue ? C'est une question sur laquelle j'aimerais avoir vos commentaires...

Pour en revenir à notre association, vous trouverez à la page 85 le procès-verbal de l'Assemblée générale des membres préparé par notre secrétaire exécutif, Roberto Racca. Vous y lirez, entre autres, que les derniers problèmes que nous avons rencontrés avec les serveurs de la CAA sont en train d'être réglés et que le dernier déploiement de la nouvelle version de Open Journal System (OJS 3.2) offre une version toujours meilleure et plus intuitive pour la gestion éditoriale de la revue Acoustique canadienne. C'est sans aucun doute une tâche qui me tient très occupé et je suis fier de la mener à bien.

Les résultats de l'enquête menée en juin 2019 sont présentés page 53 et ont conduit, comme vous vous en souvenez peut-être dans l'éditorial de l'année dernière, à plusieurs initiatives lancées par le conseil d'administration de la CAA pour mieux servir sa communauté et ses membres. Trois initiatives ont été priorisées : a) accroître la visibilité de notre association et sa présence sur les différentes plateformes de médias sociaux, notamment LinkedIn, Twitter, Facebook, YouTube, etc. avec l'aide de notre chargé des réseaux sociaux; b) intensifier les efforts en faveur des jeunes et de la nouvelle génération d'acousticiens ; c) rendre notre revue Acoustique canadienne plus accessible à la communauté de pratique, notamment en créant une nouvelle section intitulée "Practitioners' Corner (Coin des praticiens)" et en incluant la publication d'études de cas et d'autres développements pratiques en acoustique.

En raison de la situation de COVID-19, notre conférence annuelle de la Semaine canadienne de l'acoustique s'est tenue entièrement en ligne. Vous trouverez à la page 69 le rapport de l'équipe organisatrice de Sherbrooke, dirigée par Olivier Robin, qui prépare actuellement la prochaine conférence de 2021. Elle se tiendra - selon un mode hybride - à Sherbrooke (Québec), du 12 au 15 octobre 2021.

Je vous souhaite un joyeux temps des fêtes et un bon repos mérité.

Jérémie Voix
Président

more difficult to clean and sanitize, but with 2 greater advantages: a plastic film-based barrier would be completely transparent visually and... acoustically. Why such a setup isn't more widely used is a question to which I would welcome your comments...

Getting back to our association, you will find on page 85 the minutes of the Member's General Assembly prepared by our Executive Secretary, Roberto Racca. In the minutes you will find, amongst other things, that the latest issues we faced with the CAA servers are being taken care of and that the latest deployment of the new version of the Open Journal System (OJS 3.2) is continuously improving and more intuitive for the editorial management of the Canadian Acoustics journal. This is definitely a task that keeps me busy, but I am proud to be carrying it through.

The results of the survey conducted in June 2019 are presented on page 53 and these led, as you may remember from last year's editorial, to several initiatives launched by the CAA Board of Directors to better serve its community and its members. Three initiatives have been prioritized: a) increase the visibility of our association and its presence in the various social media platforms, including LinkedIn, Twitter, Facebook, YouTube, etc. with the help of our social editor; b) intensify efforts for young people and the new generation of acousticians; c) make our Canadian Acoustics journal more accessible to the community of practice, in particular by setting up a new section called "Practitioners' Corner" and including the publication of case studies and other practical developments in acoustics.

Due to the current context of the COVID-19 pandemic, our annual Acoustics Week in Canada Conference was held entirely online. You will find on page 69, a summary of the conference by the organizing team from Sherbrooke, led by Olivier Robin, who is now preparing the 2021 upcoming conference. It will be held - in a hybrid format- in Sherbrooke (Québec), October 12-15, 2021.

I wish you all a very happy holiday season.

Jérémie Voix
President


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OPTIMIZATION AND TESTING OF FLAT-PLATE TRAILING-EDGE SERRATION GEOMETRY FOR REDUCING AIRFOIL SELF-NOISE

Basim Al Tlua*[1] and Joana Rocha†[1]
Department of Mechanical and Aerospace Engineering, Carleton University, Ottawa, Ontario

Résumé

Avec une utilisation du trafic aérien et un réseau de transport en expansion, le bruit émis par les avions civils durant le décollage et l'atterrissage est devenu une préoccupation majeure pour les communautés vivant proches des aéroports. L'objectif de ce travail est d'étudier la réduction du bruit d'interaction Turbulente en Couche Limite-Bord de Fuite (TCL-BF). Afin de tester le concept de réduction du bruit, la configuration expérimentale requise est conçue et créée. La première partie de cette étude porte sur le développement d'une section d'essai en soufflerie aéroacoustique à l'Université Carleton. Les murs de la section d'essai ont été traités acoustiquement pour simuler un environnement acoustique en champ lointain avec une transmission en vol. Les deux côtés de la section d'essai en soufflerie sont équipés de chambres anéchoïques et revêtus d'écrans en tissu tendu à transparence acoustique qui agissent comme une interface entre la section d'essai et les chambres anéchoïques. Cela fourni une surface d'écoulement lisse tout en éliminant le besoin d'un receveur de jet et permet de réduire les effets d'interférence. La capacité à réduire le bruit TCL-BF par des dentelures de bord de fuite est d'abord analysée par une étude d'optimisation numérique, et les bords de fuite sont ensuite testés en soufflerie. Trois géométries de dentelure différentes sont étudiées. Les spectres de bruit ont été modélisés à l'aide du modèle semi-empirique de Howe pour une plaque plate semi-infinie, à angles d'attaque nuls et à faible nombre de Mach. Le profil aérodynamique NACA 0012 et les bords de fuite plats sont analysés et testés. Les résultats des études d'optimisation sont utilisés pour examiner l'influence des paramètres de conception de dentelure. On montre que les bords de fuite dentelés en dents de scie produisent des réductions de bruit plus importantes que les bords de fuite fendus et sinusoïdaux. Les résultats expérimentaux et d'optimisation sont ensuite comparés. Il est conclu que les résultats numériques et expérimentaux sont en accord montrant que les configurations de bord de fuite dentelées optimisées peuvent produire moins de bruit TCL-BF par rapport à la configuration de bord de fuite droit traditionnel.

Mots clefs : Bruit d'aéronef, conception de vent d'aéronef, couche limite turbulente, bruit de bord de fuite

Abstract

With an expanding network of transportation and the use of air traffic, noise radiated from civil aircraft during takeoff and landing have become a major concern to communities nearby airports. The objective of this work is to investigate the reduction of Turbulent Boundary Layer-Trailing Edge (TBL-TE) interaction noise. In order to test the concept of noise reduction, the required experimental setup is designed and created. The first part of this study focuses on developing an aeroacoustic wind tunnel test section at Carleton University. The test section walls have been acoustically treated to simulate an acoustically far-field environment with forwarding flight. The two sides of the wind tunnel test section are fitted with anechoic chambers and lined with acoustic transparency tensioned cloth screens which act as an interface between the test section and the anechoic chambers to provide a smooth flow surface while eliminating the need for a jet catcher and reducing interference effects. The ability of the trailing edge serrations to reduce TBL-TE noise is first analyzed through numerical optimization study, and trailing edges are after tested in a wind tunnel. Three different serration geometries are investigated. The noise spectra were modelled using Howe semi-empirical model for a semi-infinite flat plate, at zero angles of attack and low Mach number. NACA 0012 airfoil and flat-plate trailing edges are analyzed and tested. The results of the optimization studies are used to examine the influence of serration design parameters. It is shown that the sawtooth serrated trailing edges yield greater noise reductions than slitted and sinusoidal serrated trailing edges. Experimental and optimization results are then compared. It is concluded that numerical and experimental results are in agreement showing that optimized serrated trailing edge configurations can yield less TBL-TE noise compared to the traditional straight-trailing edge configuration.

Keywords: Aircraft noise, aircraft wind design, turbulent-boundary layer, trailing edge noise.

1 Introduction

The noise produced at and near airports is a major source of noise to surrounding communities, airport employees and, people that travel frequently. Aircraft noise has always been undesirable, and in recent years several studies have been released that make a significant connection between exposure to aircraft noise and an increased risk of cardiovascular diseases [1-3]. The problem of aircraft noise then becomes much larger when considering trends in the aerospace industry that include increasing aircraft size and speed as well as major increases in the volume of air traffic [4]. The two segments of an aircraft's flight where the most amount of noise is radiated to nearby communities are the take-off and landing phases. During the landing phase, while the engine throttle is turned down significantly, an important source of noise arises from the turbulent boundary layers (TBL) flow-structures convecting downstream across solid surfaces and interacting with the trailing edges. This mechanism of noise generation is known as the turbulent boundary layer-trailing edge (TBL-TE) noise, and its frequency spectrum is broadband in nature. TBL-TE noise is also a major source of noise in other applications, such as from wind turbines where exposure to nearby communities has been a complaint. With the growing global adaptation of alternative, environmentally friendly sources of energy, the implementation of wind turbine farms is quickly increasing. Consequently, the noise produced by wind turbines has become a significant issue in rural communities across the world where the wind farms are most often located [5].

Airframe noise research suggests that further research should be focused on noise generation mechanisms and noise reduction techniques. One promising method of reducing TBL-TE noise is by the addition of a flat-plate, serrated trailing edge extensions. This method of noise reduction has long been considered viable but has received increased attention in the last decade. The research has included experimental, theoretical and numerical studies [6-9] that have all shown the ability of trailing edge serrations to reduce TBL-TE noise. The amount of noise reduction and frequency ranges in which noise attenuation occurs varies between studies; however, it is generally agreed that for at least some part of the frequency spectrum, trailing edge serrations can produce TBL-TE noise reductions of a significant level [10].

Optimization studies have previously been conducted to reduce TBL-TE noise [11, 12]; however, they have mainly focused on altering the airfoil profile at and near the trailing edge. These studies were able to show that new, lower-noise designs could be generated through numerical optimization processes by using a semi-empirical model of noise prediction. General trends have been inferred from research involving the prediction of TBL-TE noise from serrated trailing edges.

The flow phenomena around aircraft components are complex [13-15], thus the noise generation mechanisms are difficult to be understood. Although the CFD combined with the acoustic analogy method has been widely applied in airframe noise prediction [16, 17], this method is costly and still lack of enough accuracy due to the limit of grid size, especially at high-frequency range. However, wind tunnel experiments can lead us to a better understanding of the noise mechanisms, and the results can also be used as benchmarks for the validation of numerical methods. Aeroacoustic experiments cannot be conducted at general wind tunnels due to the high background noise in the test section. A good acoustic facility must ensure a low background noise level to meet the essential requirement for aeroacoustic measurements, i.e., the background noise should be at least 10 dB lower than the noise radiated from models over a wide frequency range. The objective of this work is thus to study the predicted relative performance possibilities of trailing edge serration designs through numerical optimization, and design, manufacture, and test the optimized serration TE to confirm optimization results.

2 Wind tunnel characterization

The experiments were conducted in the medium-speed, subsonic, closed-loop wind tunnel at Carleton University (as shown in Figure. 1). The airflow is powered by a 37.3 kW (50 HP) variable-speed DC motor driving a 1.2 m axial propeller at speeds as high as 900 RPM. A variable frequency drive (VFD) modulates the rotational frequency of the fan at a resolution of 1.0Hz, and a pitot-static probe, located just downstream of the inlet, was used to calibrate the linear relationship between motor frequency and wind tunnel velocity. From the calibration, it was determined that the VFD could control the flow speed in increments of 0.9 m/s, up to a maximum speed of approximately 40 m/s. Nowadays, due to safety and component long-range issues, this velocity is limited, in this study, to 35 m/s. A series of turbulence grids precede a 9:1 contraction, which reduces the turbulence intensity levels in the center of the test section to less than 0.27%, as measured for speeds up to 15 m/s. The tunnel has a removable, rectangular test section measuring 1.83 m in length and 0.78 m x 0.51 m at the inlet in width and height, respectively.

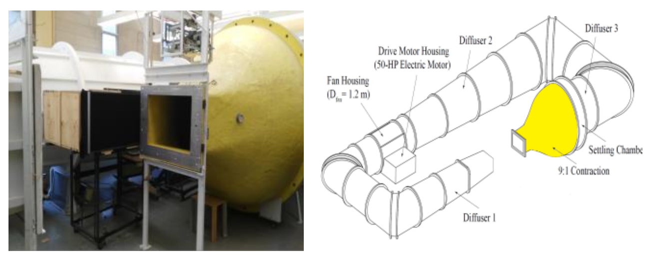


Figure 1 : Wind tunnel at Carleton University

3 New aeroacoustic test section

A new test section (shown in Figures 2 and 3) along with the surrounding anechoic chambers was completed to be used for aeroacoustic testing. This test section is a 0.78 m x 0.51 m rectangular section, 1.83 m long. The upper and lower walls of the test section are each composed of two aluminum sheet panels and contain hardware (circle aluminum material) for the vertical mounting of a two-dimensional airfoil (shown in Figure 3) midway between the acoustic windows (i.e. test section side walls), and 0.45 m from the upstream end of the test section. The two sides of the walls of the test section are made of stretched, thin-weave cloth covering a streamwise length of 1.83 m, which provides a smooth flow surface, similar to that of a hard-walled test section, and also a significant reduction in the lift interference effects when compared to that of an open-jet test section. The cloth window allows sound to pass through the walls into the anechoic chambers with very little attenuation.

[*] basim.altlua@carleton.ca
[†] Joana.Rocha@carleton.ca
[‡]

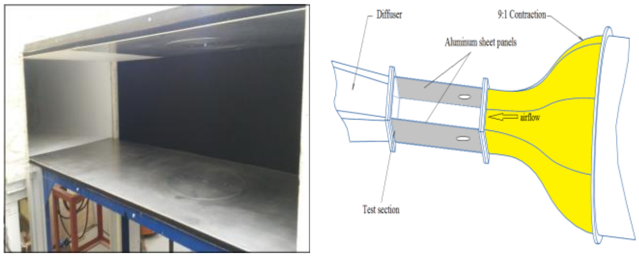


Figure 2 : Aeroacoustic test section

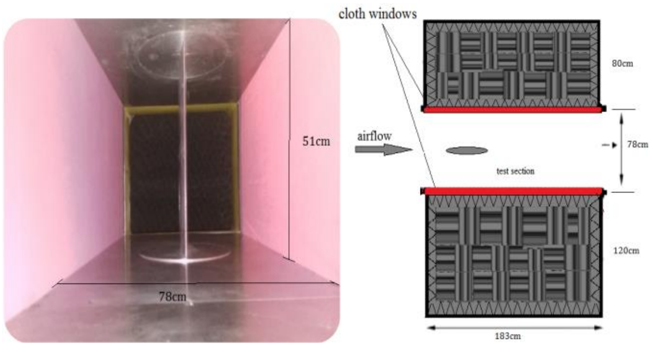


Figure 3 : Right: a cross-section through the aeroacoustics test section and anechoic as seen from above. Left: photograph was taken from downstream showing the test section interior

4 Anechoic system

4.1 Design considerations

The design of an anechoic system in the wind tunnel aims to achieve low noise radiation and low residual turbulence in the freestream. Besides acoustic and aerodynamic requirements to design anechoic system, there are also budgetary limits, as well as limits for available facility space that must be considered. The acoustical performance target is decided upon by the background noise to be at least 10 dB lower than the airfoil/flat-plate trailing edge self noise at a freestream velocity. The overall layout of the close wind tunnel with respect to the anechoic chamber, as well as some of the design details for each wind tunnel components, will be presented in the next sections.

4.2 Physical layout

The wind tunnel has an anechoic system that consists, primarily, of an aeroacoustic test section and two anechoic chambers (shown in Figure 3). The two anechoic chambers are positioned on either side of the aeroacoustic test section to capture the sound emitted through the acoustic windows and reduce sound reflections inside the section. The chambers are joined together with bolts and clamps to maintain a pressure seal. Both chambers have the same streamwise length of 1.83 m and different depths of 0.8 m right-side, and 1.2 m left-side. The chambers are lined with 0.015 m carpet bed and, 0.05 m acoustic wedged foam designed to reduce acoustic reflections.

Each chamber is sealed to the test section so that there is no airflow through either acoustic window. The regions around each of the acoustic windows are covered with a carpet-bed and acoustic foam transitions to cover up all of the hard surfaces within the chamber. The chambers are equipped with a door for access to the inside of the chamber, and for installation of data acquisition equipment. The entire system is removable so that the wind tunnel can be switched from a hard-walled configuration to an anechoic, and back again.

4.3 Acoustic transparency of the cloth windows

As with the characterization of the anechoic chambers, the acoustic transparency of the cloth windows used for the current study is discussed in detail in Remillieux et al. [18]. To investigate the acoustic transparency of the cloth sheet windows, the loudspeaker as a white noise source placed perpendicular to the window in the suction side of the anechoic chamber at a distance of 0.05 m from the window and a single calibrated microphone (Bruel & Kjaer (B&K) 4944-A, ¼ inch) was used on the other side of the window to record the sound pressure of the source as shown in Figure 4.

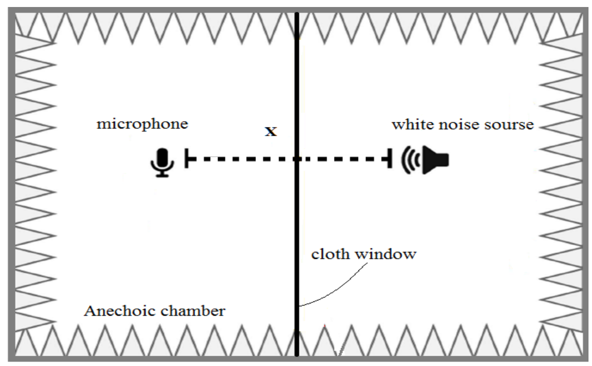


Figure 4 : Acoustic transparency of the cloth window

The sound levels, white noise, generated by the source were measured and were compared to the measured levels that the microphone would have been exposed to in the absence of the window. Sound pressure level (SPL) was used to compare the noise levels measured in the anechoic enclosure to those measured in the presence of the cloth window. The measurement is presented in Figure 5.

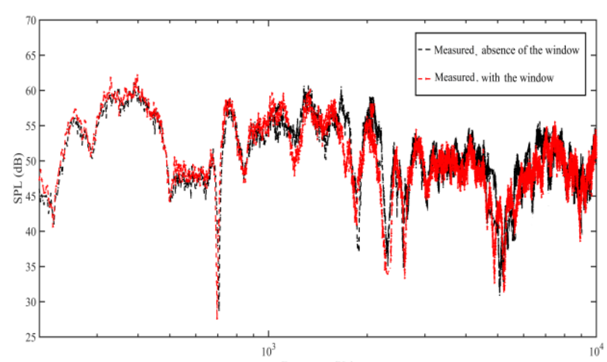


Figure 5: Attenuation of sound passing through the acoustic cloth window as a function of frequency.

Figure 5 shows that there is minimal loss through the window (~<3dB) for frequencies less than 10kHz. For all measurements presented in this paper, the frequency range of interest is significantly less than 10 kHz and thus the acoustic loss through the sheet windows can be neglected.

5 Airfoil model

For some of the tests, a NACA 0012 airfoil model was used as a benchmark test. The chord of the airfoil is 0.3 m, and the span is 0.51m. The 2D airfoil is manufactured as two halves, each one composed of three pieces with eight screws (see Figure 6). Eight holes were drilled on each side of the chord length of the airfoil, so this can be fixed on the circle rotating mechanism. The trailing edge is 0.08 m wide. The NACA 0012 airfoil wing is mounted vertically in the test section with its leading-edge (at zero angles of attack) 0.45 m downstream of the test section entrance. Angles relative to zero were set by using a calliper and scribe lines on the steel floor plate immediately beneath the model.

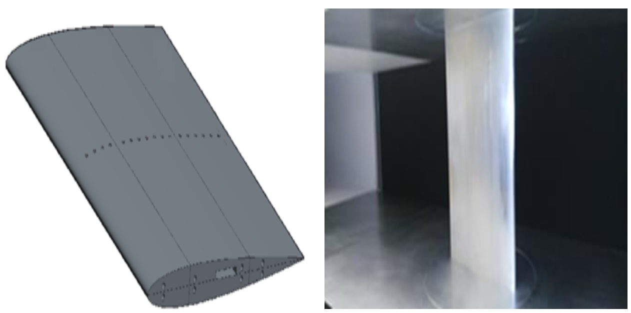


Figure 6: 2-D airfoil schematic.

6 Noise source model

In this section, the mathematical models for the prediction of noise used in this paper are presented. The underlying derivation for the noise models was originally given by Howe for sinusoidal serrations [6], and then soon after for sawtooth serrations [7]. In recent years, the model for slitted trailing edge serrations was presented by Gruber et al [19]. The modelling is based on Howe's derivation of the problem [7] which pressure fluctuations in the TBL are scattered into radiated noise by the discontinuity in the acoustic impedance that occurs at the trailing edge and includes the following assumptions:

- The flow is of low Mach number.
- The model has infinite span.
- Frozen turbulence convected past the trailing edge of a semi-infinite flat plate.
- The Kutta condition is satisfied.
- No other extraneous noise sources are present.

Figure 7 shows a sketch of the the four geometries considered in this study. The expressions defining the sawtooth, slitted and sinusoidal geometry are given in Eqs. 1, 2 and 3, respectively.

Sawtooth edge :

$$y_1 = \Gamma(y_3) = \begin{cases} (4h/\lambda)(y_3 - n\lambda), & n\lambda < y_3 < (n+0.5)\lambda \\ -(4h/\lambda)(y_3 - n\lambda), & (n-0.5)\lambda < y_3 < n\lambda \end{cases}, \quad (1)$$

$$\mathrm{n} = 0, \pm1, \pm2, \pm3, \ldots$$

Slitted edge

$$y_1 = \Gamma(y_3) = \begin{cases} -h, & n(\lambda_1 + \lambda_2) < y_3 < (n+1)\lambda_1 + n\lambda_2 \\ h, & (n+1)\lambda_1 + n\lambda_2 < y_3 < (n+1)(\lambda_1 + \lambda_2) \end{cases}, \quad (2)$$

$$\mathrm{n} = 0, \pm1, \pm2, \pm3, \ldots$$

Sinusoidal edge:

$$y_1 = \Gamma(y_3) = h\cos\left(\frac{2\pi y_3}{\lambda}\right) \quad (3)$$

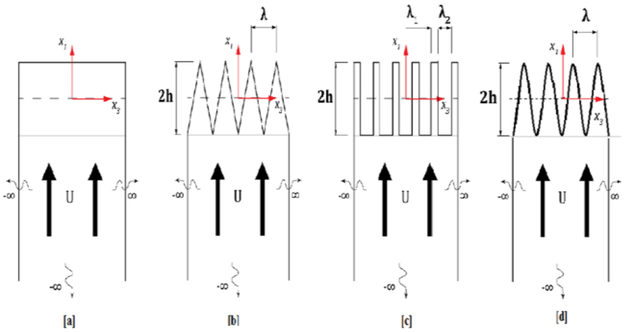


Figure 7: 2-D schematic drawings of flat plate [a] Straight, [b] Swatooth [c] Slitted and, [d] Sinusoidal TE extensions.

The scattered pressure produced at the trailing edge is defined in terms of the Green's function and the turbulence blocked pressure, P_b, as follows [7]:

$$P_s(\mathbf{x},\omega) = \frac{i}{2}\int_{-\infty}^{\infty} \mathrm{d}y_3 \int_{-\infty}^{\Gamma(y_3)} \mathrm{d}y_1 \times \int_{-\infty}^{\infty} \gamma(K)[\mathrm{G}(\mathbf{x}, y_1, y_3; \omega)]\, \mathrm{P_b}(\mathbf{K}; \omega) \mathrm{e}^{\mathrm{i}(K_1 y_1 + K_3 y_3)} \mathrm{d}^2\mathbf{K} \quad (4)$$

where $\mathbf{K} = (K_1, 0, K_3)$ is the boundary layer turbulent wavenumber vector, and $\gamma(K) = \sqrt{(\kappa^2 - |\mathbf{K}|^2)}$, for $\kappa > |\mathbf{K}|$ and $\gamma(K) = i\sqrt{(|\mathbf{K}|^2 - \kappa^2)}$, for $\kappa < |\mathbf{K}|$.

The Green's function is given by Howe in [6] and is based on applying the slender-wing approximation to the Green's function for straight trailing edges. P_b is obtained from an empirical model for the turbulent wall pressure wave-number-frequency spectrum developed by Chase [20]:

$$P_s(\mathbf{x},\omega) = \frac{C_m \rho^2 u_*^3 K_1^2 \delta^5}{\left[\left(K_1 - \frac{\omega}{U_c}\right)^2 \left(\frac{\delta U_c}{3u_*}\right) + (\mathbf{K}\delta)^2 + \varepsilon^2\right]^{\frac{5}{2}}} \quad (5)$$

in which the friction velocity, $u_* = 0.03U$, the convection velocity, $U_c = 0.7U$, and the empirical constants, $C_m = 0.1553$ and $\varepsilon = 1.33$.

The final, non-dimensional, forms of the trailing edge noise spectrum for the straight, sawtooth, slitted and sinusoidal trailing edge geometries are the following:

$$\Psi_0(\omega) = \frac{\left(\frac{\omega\delta}{U_c}\right)^2}{\left[\frac{\omega\delta}{U_c} + \varepsilon^2\right]^2} \quad (6)$$

$$\Psi_{Saw}(\omega) = 8\left(\frac{h}{\delta}\right)^2\left(\frac{\omega h}{U_c}\right)\times \sum_{n=-\infty}^{\infty}\frac{\left[1-\cos\left(\frac{2\omega h}{U_c}\right)/\cos(n\pi)\right]\left[\left(\frac{\omega h}{U_c}\right)^2+\left(2n\pi\frac{h}{\lambda}\right)^2\right]}{\left[(n\pi)^2-\left(\frac{2\omega h}{U_c}\right)^2\right]^2\left[\left(\frac{\omega h}{U_c}\right)^2+\left(2n\pi\frac{h}{\lambda}\right)^2+\left(\frac{\varepsilon h}{\delta}\right)^2\right]^2} \quad (7)$$

$$\Psi_{Slit}(\omega) = \sum_{n=-\infty}^{\infty}\Theta\Theta^{*}\frac{\left[\left(\frac{\omega\delta}{U_c}\right)^2+\left(2n\pi\frac{\delta}{\lambda_1+\lambda_2}\right)^2\right]^2}{\left[\left(\frac{\omega\delta}{U_c}\right)^2+\left(2n\pi\frac{\delta}{\lambda_1+\lambda_2}\right)^2+(\varepsilon)^2\right]^2} \quad (8)$$

$$\Theta(K,\lambda_1,\lambda_2,h) = n^{-1}\left[\left(e^{\frac{2in\pi\lambda_1}{\lambda_1+\lambda_2}}-1\right)e^{iK_1h} + \left(1-e^{\frac{-2in\pi\lambda_1}{\lambda_1+\lambda_2}}\right)e^{-iK_1h}\right] \quad (9)$$

$$\Psi_{Sin}(\omega) = \left(\frac{\omega h}{U_c}\right)\sum_{n=-\infty}^{\infty}J_n^2\left(\frac{\omega h}{U_c}\right)\frac{\left|\left(\frac{\omega\delta}{U_c}\right)^2+\left(2n\pi\frac{\delta}{\lambda}\right)^2\right|^2}{\left[\left(\frac{\omega\delta}{U_c}\right)^2+\left(2n\pi\frac{\delta}{\lambda}\right)^2+\varepsilon^2\right]^2} \quad (10)$$

The boundary layer thickness, δ, at the airfoil trailing is an important parameter in determining the noise performance of trailing edge serrations. The TBL thickness used in the noise prediction is calculated as following [21, 22]:

$$\delta = \frac{0.37c\left[1+\left(\frac{R_{ec}}{6.9\times10^7}\right)^2\right]^{\frac{1}{10}}}{R_{ec}^{\frac{1}{5}}} \quad (11)$$

The non-dimensional overall sound pressure level ($OASPL_{norm}$) describes the total amount of noise produced across the desired frequency range. The $OASPL_{norm}$ is used both an objective function and for the comparison of various trailing edge designs to a straight trailing edge. The $OASPL_{norm}$ is calculated as follows:

$$OASPL_{norm} = 10\log_{10}\left(\int_{\omega_{min}}^{\omega_{max}}\Psi(\omega)d\omega\right) \quad (12)$$

where ω_{min} and ω_{max} are the lower and upper bounds on the frequency range of interest respectively and, Ψ(ω) can be obtained from any of Eqs. 6 to 10 according to the geometry of interest.

7 Numerical optimization methods

This study examines three different optimization problems, which are given below in proper form in Eqs. (13) to (15). These equations correspond to the single-size optimization of sawtooth (see Figure 6b), slitted (see Figure 6c) and sinusoidal (see Figure 6d) TE geometries, respectively. In each case, the optimum design is the single-size of serration that produces the least amount of total noise overall frequencies between 0.1 Hz and 10 kHz.

$$\begin{aligned}&\underset{h,\lambda}{\text{minimize}} && Z = OASPL_{norm\_saw}(h,\lambda),\\ &\text{subject to} && 0\le h\le h_{max}\\ &&& \lambda_{min}\le\lambda\le\lambda_{max}\end{aligned} \quad (13)$$

$$\begin{aligned}&\underset{h,\lambda}{\text{minimize}} && Z = OASPL_{norm\_slit}(h,\lambda_1,\lambda_2),\\ &\text{subject to} && 0\le h\le h_{max}\\ &&& (\lambda_1)_{min}\le\lambda_1\le(\lambda_1)_{max}\\ &&& (\lambda_2)_{min}\le\lambda_2\le(\lambda_2)_{max}\end{aligned} \quad (14)$$

$$\begin{aligned}&\underset{h,\lambda}{\text{minimize}} && Z = OASPL_{norm\_sinu}(h,\lambda),\\ &\text{subject to} && 0\le h\le h_{max}\\ &&& \lambda_{min}\le\lambda\le\lambda_{max}\end{aligned} \quad (15)$$

where Z is the objective function value; h_{max} is the largest feasible serration amplitude corresponding to the sawtooth, slitted and sinusoidal geometries accordingly; (λ_{min}) and (λ_{max}) are the smallest and largest feasible sawtooth and sinusoidal widths, respectively; $(\lambda_1)_{min}$ and $(\lambda_1)_{max}$ are the smallest and largest feasible slit widths, respectively; and $(\lambda_2)_{min}$ and $(\lambda_2)_{max}$ are the smallest and largest feasible gap widths, respectively. A summary of the optimization studies conducted for this work is presented in Table 1.

8 Results and discussion

8.1 Background noise levels

The background noise of the wind tunnel is measured in the anechoic chamber with a single calibrated B&K microphone. Figure 8 shows empty test-section background sound pressure levels (SPL) in the starboard-side anechoic chamber as a function of flow speed, 0 m/s to 24 m/s. These measurements were made 1.4 m from the test-section center.

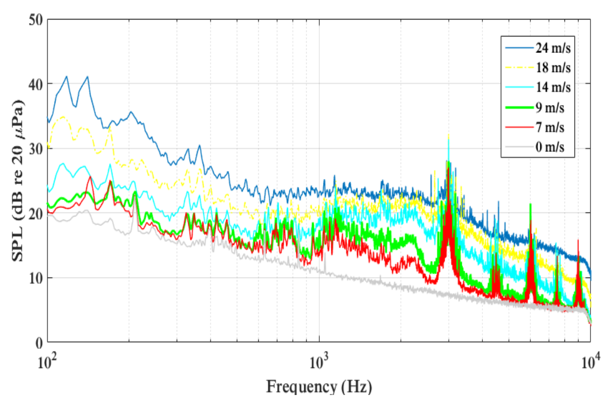


Figure 8: SPL in the starboard-side anechoic chamber (1.4 m from the test-section center) as a function of flow speed in the empty test section.

The highest spectral level can be seen at low frequencies (100-500 Hz). Background noise levels at frequencies less than 500 Hz are mostly tones generated by the wind tunnel

Table1: Optimization trials and associated design variable bounds for U = 24m/s.

Study No	Geometry	Lower Design Variables Bound (mm)			Upper Design Variables Bound (mm)		
		λ_{1min}	λ_{2min}	h_{min}	λ_{1max}	λ_{2max}	h_{max}
SS-Saw-1	Sawtooth	10	-	0	30	-	35
SS-Saw-2	Sawtooth	15	-	0	35	-	40
SS-Saw-3	Sawtooth	20	-	0	40	-	30
SS-Saw-4	Sawtooth	25	-	0	35	-	37.5
SS-Slit-1	Slitted	10	10	0	40	30	35
SS-Slit-2	Slitted	15	20	0	35	40	40
SS-Slit-3	Slitted	10	25	0	30	35	37.5
SS-Slit-4	Slitted	20	20	0	30	40	40
SS-Sinu-1	Sinusoidal	15	-	0	40	-	35
SS -Sinu-2	Sinusoidal	10	-	0	35	-	30
SS -Sinu-3	Sinusoidal	20	-	0	45	-	40
SS -Sinu-4	Sinusoidal	25	-	2	30	-	37.5

fan and levels at frequencies greater than 500 Hz are primarily broadband and believed to be due to a combination of oise sources including the fan, turning vanes, and scrubbing noise from flow surfaces in and around the test section. The peaks showed in 3 kHz, 4.5 kHz and 6 kHz are mostly associated with motor tones.

The Overall Sound Pressure Level, OASPL, is obtained by integrating the noise spectrum from 0.1 kHz to 10 kHz. Figure 9 shows the dependence of OASPL on free-stream velocity; the 5th power law is satisfied, which is similar to other closed-circuit type wind tunnels.

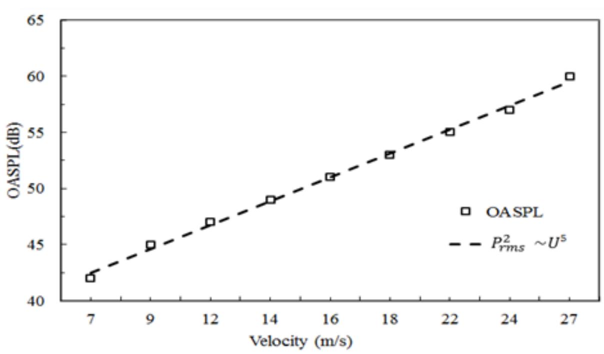


Figure 9 : The overall sound pressure level of background noise as a function of free-stream velocity.

To estimate the acoustic performance, the A-weighted overall sound pressure level, OASPL, is compared to other acoustic facilities around the world. Since the nozzle dimensions and microphone positions are different from each other, the measured results must be transformed before comparing with each other [7]:

$$\mathrm{OASPL}_{\mathrm{corrected}} = \mathrm{OASPL}_{\mathrm{measured}} - 10\log_{10}(S/R^2) \qquad (16)$$

where R and S are the distance from the microphone to the wind tunnel center-line and nozzle exit area, respectively.

The background noise of Carleton University wind tunnel is scaled using Eq. 16, and the results are shown in Figure 10. The background noise of other acoustic facilities with data obtained from the literature [23-26] is also plotted in Figure 10 for comparison. The results indicate that the background noise of the Carleton University wind tunnel is comparable with other aeroacoustic wind tunnels.

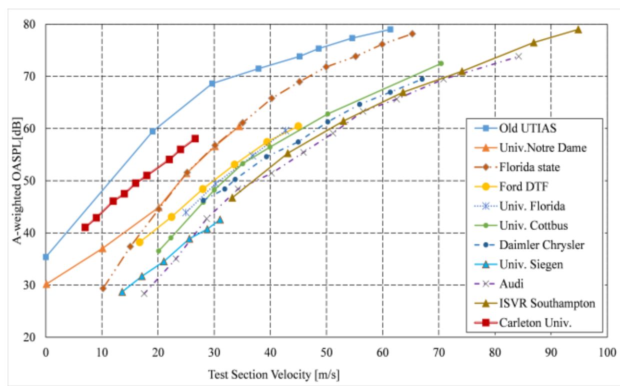


Figure 10: Comparison of A-weight sound pressure level of Carleton University wind tunnel to other acoustic facilities worldwide.

8.2 Far-field trailing edge noise measurements

Measurements of the airfoil TE noise

NACA0012 airfoil with straight and sawtooth trailing edge (see Figure 11) was submerged within the potential core of the jet to assess the trailing edge self-noise in relation to the wind tunnel background noise. The airfoil was held at zero angles of attack by side plates extended from the nozzle sidewalls. The radiated noise was measured at 1.4 m from the center of the trailing edge in the starboard-side, which corresponds to a 90^0 of polar angle θ.

At first, the background noise of the wind tunnel was measured under a freestream velocity of 14 m/s and 24 m/s. The airfoil with straight TE as a reference and the same airfoil with sawtooth TE were then attached to the sidewalls, and the same freestream velocities were repeated. The result of the TE self-noise spectra of these cases is plotted in Figure 11. The Figure shows that the serration geometry is effective in reducing the trailing edge noise component. The TE self-noise measurement is seen to be from ~5 to ~15 dB above the background wind tunnel noise within the frequency range from 0.1kHz to ~ 3kHz, which guarantees the validity of the results.

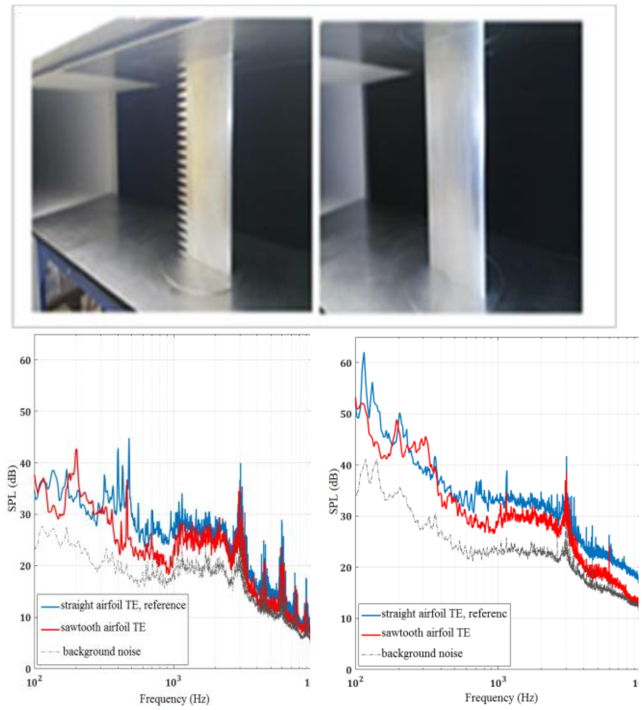


Figure 11: Measured SPL spectra for NACA0012 airfoil and the same airfoil with sawtooth TE at free-stream velocities of (Left) 14 m/s and (Right) 24 m/s at Carleton University anechoic wind tunnel. The background noise spectra are also shown in this figure for comparaison.

Measurements of the flat-plate TE noise

A 3 mm thickness flat-plate, 0.30 m in a chord and 0.51 m in span, was submerged within the potential core of the jet to assess the trailing edge self-noise in relation to the wind tunnel background noise. The flat-plate was held at zero angles of attack by side plates extended from the nozzle sidewalls. The radiated noise was measured at 1.4 m from the center of the trailing edge in the starboard-side, which corresponds to a 90^0 of polar angle θ.

Similarly, to the airfoil, the background noise of the wind tunnel was measured first under a freestream velocity of 14 m/s and 24 m/s. The flat-plate with straight TE as a reference and the same flat-plate with slitted TE were then attached to the sidewalls, and the same freestream velocities were repeated. The result of the TE self-noise spectra of these cases is plotted in Figure 12. The figure indicates that the serration geometry is effective in reducing the trailing edge self-noise component and the TE self-noise measurement is seen to be from ~ 4 to ~16 dB above the background wind tunnel noise, within the frequency range from 0.1kHz to ~ 3kHz, which guarantees the validity of the results.

8.3 Optimization results

This section presents the optimization results from the analyses that used the sawtooth, slitted and sinusoidal geometry. The serrations' designs are optimized to find the single size of each tooth geometry that produces the least noise over the entire frequency spectrum of interest (0.1kHz to 10 kHz) for each set of constraints examined. A summary of the optimized designs from each study, and their respective $OASPL_{norm}$, is shown in Table 2.

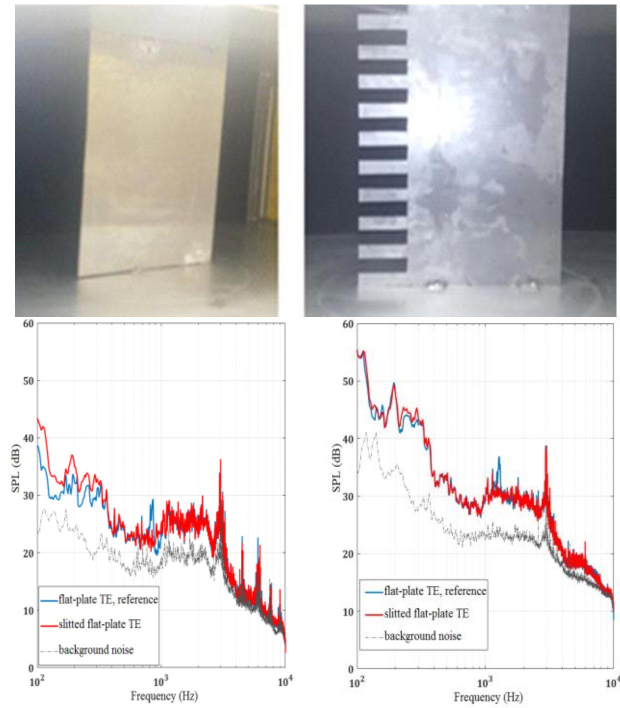


Figure 12 : Far-field acoustic spectra for the reference flat-plate and the flat-plate with trailing edge serrations, slitted TE, at freestream velocities of (Left) 14 m/s and (Right) 24 m/s. The background noise spectra are also shown in this figure for comparison.

Verification of the noise model

Noise models previously defined in Eqns. 6 to 10 were coded in Matlab to be used. In order to verify the Matlab code, the function outputs were compared to results published by Howe et al. [7] (for Eq. 7), by Azarpeyvand et al. [27] (for Eq. 8) and by Howe et al. [7] (for Eq. 10). Based on the thorough comparison in this analysis, it was concluded that the Matlab functions used produce identical results to the analytical equivalents, as shown in Figures 13, 14 and 15.

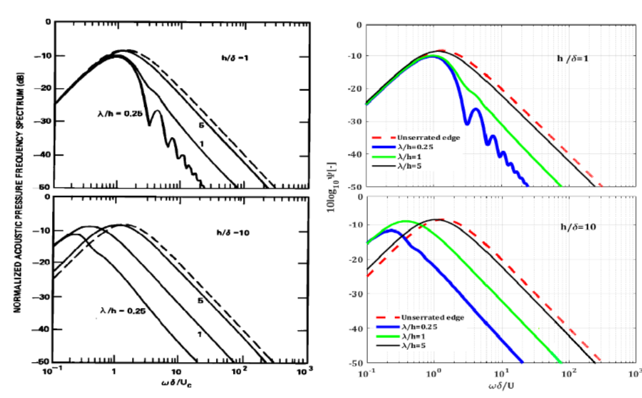
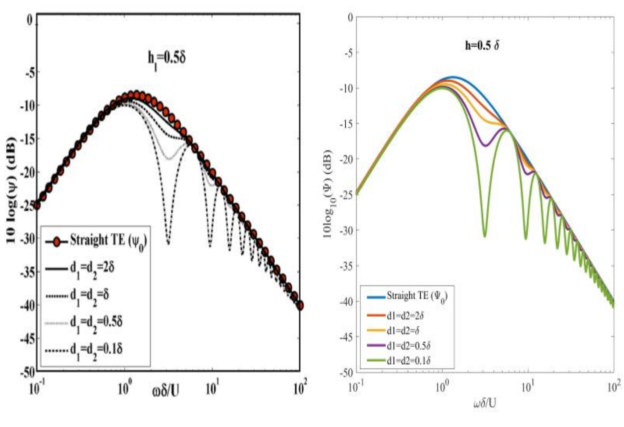


Figure 13: Normalized spectrum of noise produced by a low Mach number flow over a sawtooth TE: (a) from [7] Eqn. (17) ;(b) Matlab code.

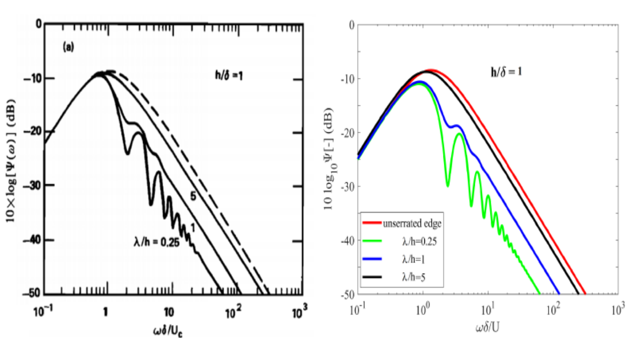
Table2: Optimized designs from each study and noise produced by each trailing edge

Study No	**Optimal Geometry (mm)**			**OASPL$_{norm}$ [dB]**	$\int_{\omega_{min}}^{\omega_{max}} (\Psi i) = 10^{\frac{OASPL\_norm}{10}}$	ΔOASPL$_{norm}$ = $10\log_{10}\left(\int_{\omega_{min}}^{\omega_{max}} \Psi_0 / \int_{\omega_{min}}^{\omega_{max}} \Psi_i\right)$
	λ_{1opt}	λ_{2opt}	h_{opt}			
Straight TE	-	-	-	30.1	1023.3	-
SS-Saw-1	10	-	35	16.7	46.7	13.3
SS-Saw-2	15	-	40	18.2	66.1	11.9
SS-Saw-3	20	-	30	21.5	141.2	8.6
SS-Saw-4	25	-	37.5	21.6	181.9	7.5
SS-Slit-1	10	10	6.4	27.9	616.6	2.2
SS-Slit-2	15	20	5.8	28.5	707.9	1.6
SS-Slit-3	10	25	6.0	28.5	707.9	1.6
SS-Slit-4	20	20	5.6	28.6	724.4	1.5
SS-Sinu-1	15	-	35	21.1	128.8	9
SS-Sinu-2	10	-	30	20.0	100	10.1
SS-Sinu-3	20	-	40	21.9	151.9	8.2
SS-Sinu-4	25	-	37.5	23.1	204.2	7



(a) (b)

Figure 14: Normalized spectrum of noise produced by a low Mach number flow over a slitted TE: (a) from [27] Eqn. (10); (b) Matlab Code



(a) (b)

Figure 15. Normalized spectrum of noise produced by a low Mach number flow over a sinusoidal TE: (a) from [7] Eqn. (5.6); (b) Matlab Code.

Optimization of single-size sawtooth serrations

The noise spectrums for both a straight TE and each of the optimized, single-size, sawtooth TE designs are given in Figure 16. The optimized single-size sawtooth design, which produced the least noise, was obtained in the study of SS-Saw-1.

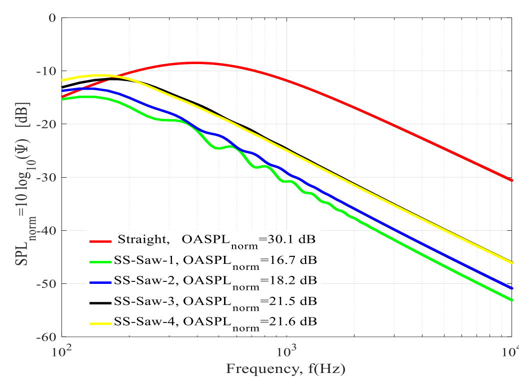


Figure 16. Normalized spectrum plotted as a function of frequency between 0.1kHz and 10kHz for OASPL$_{norm}$ optimized sawtooth trailing edge profiles.

This study applied the largest upper limit, and the smallest lower limit on h and λ respectively compared to the other studies in the SS-Saw group. The OASPL$_{norm}$ produced by SS-Saw-1 was 16.7 dB, corresponding to a 30.1 dB of a straight trailing edge and the reduction in ΔOASPL$_{norm}$ is 13.1 dB compared to a straight trailing edge (see the Table 2 for more details).

Optimization of single-size slitted serrations

The noise spectrums for both a straight TE and each of the optimized, single-size, slitted TE designs are given in Figure 17. Of the single-size slit optimization studies, the design that produced the least noise was SS-Slit-1, which produced an OASPL$_{norm}$ of 27.9 dB corresponding to a 30.1 dB of a straight trailing edge and the reduction in ΔOASPL$_{norm}$ is 2.2 dB compared to a straight trailing edge (see the Table 2 for more details). Similar to the single-size sawtooth optimization, SS-Slit-1 also applied the smallest lower limits on widths, λ_1 and λ_2 and the upper limit on the slit amplitude, h, is 6.4 dB. The optimum widths are seen to always be equal to their lower limits of $(\lambda_1)_{min}$ and $(\lambda_2)_{min}$.

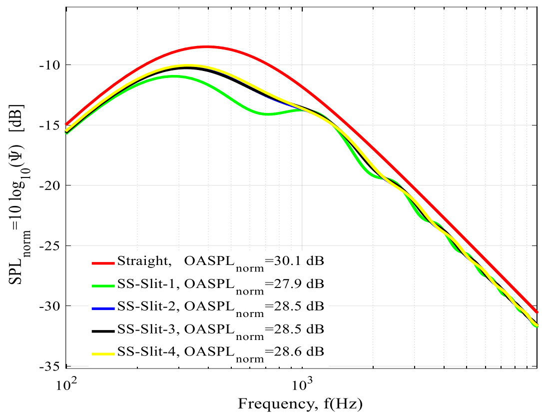


Figure 17: Normalized spectrum plotted as a function of frequency between 0.1KHz and 10kHz for OASPL$_{norm}$ optimized slitted trailing edge profiles

Optimization of single-size sinusoidal serrations

The noise spectrums for both a straight TE and each of the optimized, single-size, sinusoidal TE designs are given in Figure 18. The optimized single-size sinusoidal design, which produced the least noise, was obtained in the study of SS-Sinu-2.

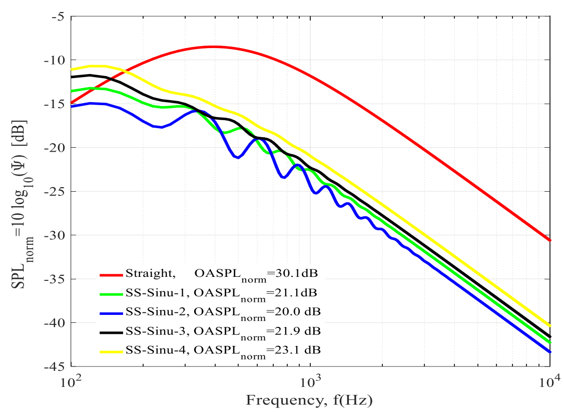


Figure 18. Normalized spectrum plotted as a function of frequency between 0.1kHz and 10kHz for OASPL$_{norm}$ optimized sinusoidal trailing edge profiles.

Similar to the single-size sawtooth optimization, this study applied the largest upper limit, and the smallest lower limit on h, and λ respectively compared to the other studies in the SS-Sinu group. The OASPL$_{norm}$ produced by SS-Sinu-2 was 20.0 dB, corresponding to a 30.1 dB of a straight trailing edge and the reduction in ΔOASPLnorm is 10.1 dB compared to a straight trailing edge (see the Table 2 for more details).

Each of the optimum designs in all studies, (see Figure 19), sawtooth, slitted and sinusoidal TE produces a lower OASPL$_{norm}$ than the straight TE ; however, significant variations are seen in the amount of reduction achieved between the three, TE designs. This observation suggests that the optimization process can produce TE serration designs that produce less noise than designs that have previously been studied, and whose dimensions were chosen manually. Furthermore, based on our analysis, the sawtooth serration, SS-Saw-1, provides the greatest noise reduction, ΔOASPL$_{norm}$, over a wide range of frequencies as shown in Figure 19.

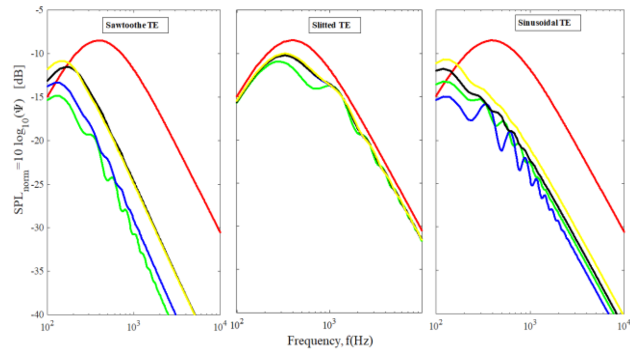


Figure 19: The compression between the optimum serrations.

8.4 Experimental results and comparison with numerical results

A comparison of the far-field noise SPL spectrum, measured at 90º overhead of the airfoil and flat-plate, trailing edge, between the best optimum serrated (SS-Saw-1, SS-Slit-1 and SS-Sinu-2) and the straight trailing edge, as defined in Table 2, is shown in Figure 20. Below ~250 Hz, an airfoil TE noise reduction relative to the straight trailing edge of between ~1 to ~ 6 dB can be seen for all trailing edge treatments.

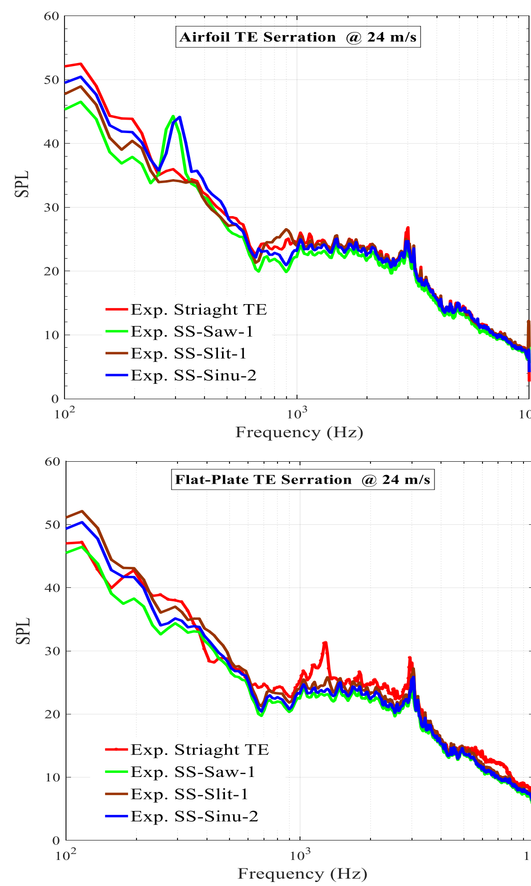


Figure 20: Measured far-field noise spectrum showing a comparison between straight and the sawtooth, slitted and sinusoidal TE with airfoil and flat-plate at 0^0 AoA and U= 24 m/s.

A comparison of the noise reduction, ΔSPL, between the predicted/optimized and experimental data for various optimum serrated trailing edges is shown in Figure 21. The level of predicted noise reduction is approximately ~29 to 52 dB higher than the measured reduction for SS-Saw-1 and SS-Sinu-2 and approximately ~1 to 3 dB for SS-Slit-1. This is in trend agreement with the previous results shown in [28] for sawtooth serrations. The predicted noise reduction tends to increase with frequency, while the measured one decreases with frequency.

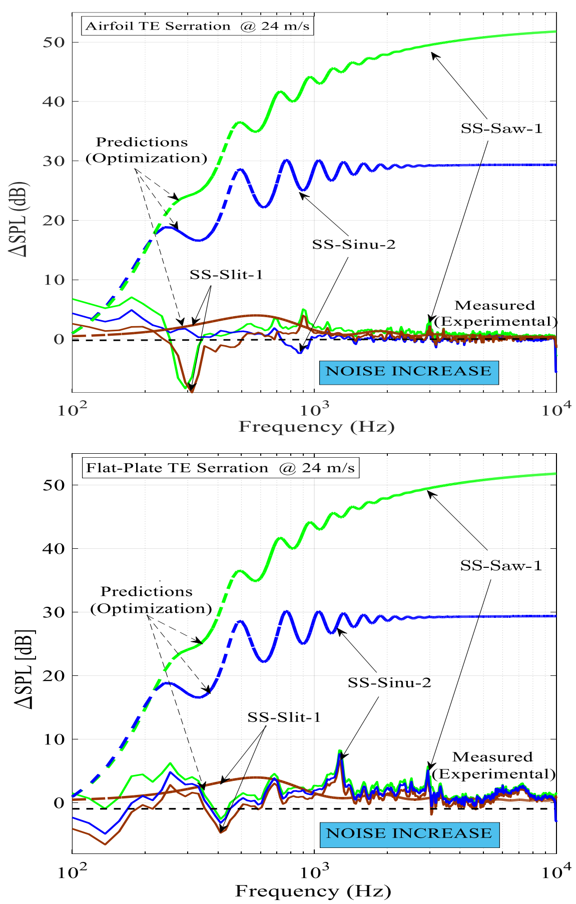


Figure 21 : Broadband noise reduction predicted by Howe (Dashed) and measured experimentally (Solid) for serration profiles SS-Saw-1, SS-Slit-1 and SS-Sinu-2 - Experimental data with airfoil and flat-plate at 0^0 AoA and U= 24 m/s.

The strong oscillations observed in the predicted noise reduction in Figure 21 are due to interference between the root and the tip of the serrations, which are not observed in the experimental data. Note that the oscillations observed in the experimental spectra are characteristics of trailing edge noise and are not related to the serrated edges as described by Amiet [29]. The predicted oscillations from the optimization are a direct consequence of Howe's model simplifying assumption; i.e., that the scattering process is the predominant source of TE noise with no extraneous sources present. However, experimental results suggest that extraneous noise sources may be present due to unsteadiness close to the serrations. While the noise reduction amounts from predictions and experimental data differ, Howe's model is still very useful for the optimization work to determine the best TE configurations which reduced the noise radiated

The discrepancies observed in Figure 21 between the optimization and measured noise reductions for serrated trailing edges speculates on the possible reasons:

- Assumption that the surface pressure in the boundary layer at the trailing edge is not affected by the serrations, but it is locally affected by the serration. However, this effect is likely to be small [28].
- The quadrupole sources in the boundary layer of the airfoil, upstream of the trailing are not accounted for in the theoretical far-field radiation.
- Numerically shown by Jones and Sandberg [30], the unsteadiness close to the serration due to horse-shoe vortices can be a source of extraneous noise

9 Conclusion

An aeroacoustic wind tunnel test section has been built at Carleton University. The tunnel has a rectangular test section with dimensions of 0.78 m in width, 0.51 m in height and 1.83 m long. Its aeroacoustic performance is measured. Results show that the background noise can be comparable with other aeroacoustic wind tunnels worldwide. A simplified airfoil and flat-plate TE noise are tested as a benchmark test. Results show that the serration geometry is effective in reducing noise and, the noise radiated from the TE is at least 10 dB higher than the background noise, satisfying the requirements for aeroacoustic measurements.

Three different geometrical profiles of trailing edge serrations have been optimized for the reduction of TBL-TE noise. The optimum width for the three, sawtooth, slitted and sinusoidal serrations, are the smallest allowable one in the overall spectrum frequencies. The optimum single-size sawtooth and sinusoidal always has the largest allowable amplitude whereas the optimum single-size slit has a specific amplitude value to optimize the balance.

Noise radiation from optimized trailing edges with different serrations, sawtooth, slitted and sinusoidal, has been investigated. It has been shown that the TE serration design can have a significant effect on the level of noise reduction. It has been shown that numerical and experimental results are in agreement showing that optimized serrated trailing edge configurations can yield less TBL-TE noise compared to the traditional straight trailing-edge configuration. Moreover, based on the optimization and experimental analyses, the sawtooth serration provides the greatest noise reduction over a wider range of frequencies when compared to slitted and sinusoidal TE serrations.

Acknowledgments

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Nomenclature

f	frequency
G(x,y;ω)	Green's function
h	serration amplitude
i	imaginary number
K	wavenumber vector
K_1	streamwise wavenumber
K_3	spanwise wavenumber
P_b	blocked pressure
P_s	scattered pressure
$\mathbf{R_{ec}}$	Reynolds number
U	mean flow speed
U_c	convection velocity (U_c=0.7U)
ω	angular frequency
χ_1, χ_2, χ_3	Cartesian coordinate system
Z	objective function value
$\Gamma(y_3)$	serration profile
λ	sawtooth and sinusoidal serration width
λ_1, λ_2	slitted serration width and gap width
δ	turbulent boundary layer thickness
κ	acoustic wavenumber (κ= ω/c)
ψ	non-dimensional trailing edge noise spectrum

EVOLUTION OF SOME MICROPHONE ARRAYS IN SOUND FIELD REPRODUCTION. APPLICATIONS INSIDE TWO HISTORICAL THEATRES

Lamberto Tronchin *[1] Antonella Bevilacqua †[2] et Francesca Merli ‡[3]
[1] Department of Architecture, University of Bologna, Italy
[2] CIDEA, University of Parma, Italy
[3] CIRI, University of Bologna, Italy

Résumé

Les termes « espaces de performances artistiques » caractérisent un type bien spécifique de bâtiments, régulièrement soumis à des tests acoustiques depuis des décennies, et ce, à partir de différentes techniques et équipements. La portée de cet article réside dans l'application et la comparaison successive de certains réseaux de microphones, selon leurs caractéristiques acoustiques, capables de collecter des informations utiles afin à la fois pour déterminer les paramètres acoustiques d'une pièce puis pour reconstruire les champs sonores 3D. L'exécution des mesures acoustiques avec différents équipements a été réalisée dans deux théâtres italiens, dans le cadre du patrimoine culturel du XVIIIe siècle. Le microphone Soundfield, utilisé pour le Teatro 1763 de Bologne, est une technologie limitée par rapport à une nouvelle génération de microphone armé de plusieurs canaux contrôlés individuellement, comme utilisé dans Teatro Sociale de Gualtieri. Ces technologies ont été considérées comme une manière coplanaire d'étudier l'acoustique d'un bâtiment historique. Les auteurs de cet article illustrent les résultats des principaux paramètres acoustiques des deux théâtres sélectionnés, autres qu'une comparaison d'une qualité différente d'analyse graphique dans le rendu de la directivité des rayons sonores en fonction des différents équipements employés.

Mots clefs: Acoustique des salles; Auralisation; Théâtres italiens; Réponse impulsionnelle; Antenne de microphones.

Abstract

Performing arts spaces characterise a specific group of buildings, always subject to be tested under the acoustical point of view with different techniques and equipment through the decades. Scope of this paper is the application and consecutive comparison of some microphone arrays, based on their acoustical characteristics, capable to gather useful information in order to both determine the acoustical parameters of a room and reconstruction of the 3D sound fields. The execution of the acoustical measurements with different equipment setup has been taken in two Italian theatres, as part of the cultural heritage of the 18th century. The Soundfield microphone, employed for the Teatro 1763 of Bologna, is a limited technology if compared with a new generation of microphone armed with multiple channels individually controlled, as utilised in Teatro Sociale of Gualtieri. These technologies have been considered as a coplanar way of how to study the acoustics of a historical building. The authors of this paper illustrate the results of the main acoustical parameters of the two selected theatres, other than a comparison of a different quality of graphical analysis in rendering the directivity of the sound rays based on different equipment employed.

Keywords: Room acoustics; Auralization; Italian theatres; Impulse response; Microphone array.

1 Introduction

Many theatres in Italy are considered quite important for their unique acoustical characteristics. Especially those built between the 17th and 19th century are considered as the referent symbols for the theatrical acoustics across Europe that need to be faithfully reproduced in order to be preserved to the next generations in case of damage.

The collection of acoustical behaviour of historical theatres and opera houses, initially proposed by Gerzon [1], became extremely important after the fire of two Italian theatres: Teatro Petruzzelli of Bari and Gran Teatro La Fenice of Venice [2].

After these sorrowful events, many challenges were achieved to standardise the measurement procedures for theatres and auditoria, considering their importance as an intangible cultural heritage.

Room conditions and specific suggestions for the selection of equipment have been considered in order to entirely recreate the acoustics of such historical buildings. Furthermore, this paper highlights the capabilities of different instrumentations that can be used to accomplish the scope of recreating a particular sound field.

The application of the acoustical measuring techniques, with the acoustical maps overlapped to a 360º view obtained after data processing, have been executed inside Teatro 1763 of Bologna [3] and Teatro Sociale of Gualtieri, similar for volume size.

* lamberto.tronchin@unibo.it
† antonella.bevilacqua@unipr.it
‡ francesca.merli8@unibo.it

In order to obtain a reasonable room impulse response (RIR), these specifications became quite important whenever the auralization is intended to be performed.

2 Equipment and Methodologies

2.1 General considerations on equipment selection

The characteristics of the microphone represent an important matter for both measurements and auralization reconstruction.

The necessity of the stereophonic audio has been always appreciated by the listeners because of the potentiality of the sound source localization, which creates a more involvement effect. The progress undertaken by the electronics industry directed its development towards an ever-increasing number of microphones' channels, in order to make the stereophony more detailed, in line with the need of localising the sound source in the space and of faithfully post-reproducing any musical event.

As such, shapes of microphone arrays, realised by organising the capsules of the microphone in a specific way, have the scope of gathering much more information about the soundscape than what is suitable with only one transducer. With this technique, the stereophony can be acquired by a combination of signals coming from different capsules elaborated by a decoding system. The most popular decoding system is Ambisonic, which is capable of decomposing the 3D sound field in spherical harmonics determined at a certain order [4].

Although a common omnidirectional microphone armed with one transducer is good enough to report the acoustical characteristics of a room, representing the scope for many building acoustics activities, it is quite tough with this kind of equipment reproducing the effective directivity pattern of any real source.

However, some of the microphones' outfits are even not capable to reproduce a virtual microphone, which is considered as a sound signal equivalent to what would have been registered a microphone-equipped with arbitrary orientation and with a maximum order of directivity.

The measurement technique employed in Teatro 1763 of Bologna was realised by using a tetrahedral microphone array (i.e. Soundfield), composed of 4 cardioid capsules organised on the faces of a regular tetrahedron. This B-format setting is capable of rebuilding a 3D sound field at a specific point of the space [5].

The evolution of the tetrahedral array is the spherical array, which allows a spherical disposition of the capsules having the equal sensibility to the arrival of the sound waves coming from every direction. The more the number of capsules composing the array, the better is the reconstruction of the 3D sound field and the synthesis of directivities [6].

When the goal of the measurements is to determine the effective directivity patterns existing in the real world (e.g. musical instruments or human voice), a microphone system having individual control of singular transducers is required. This is the technique employed during the acoustical survey undertaken in Teatro Sociale of Gualtieri, by using a 32-channel microphone (i.e. em32 Eigenmike®) equipped with 32 capsules uniformly distributed on a spherical surface, able to be controlled individually.

2.2 Traditional measurement technique of a 3D sound distribution inside Teatro 1763 of Bologna

The aim of the measurement technique employed for Teatro 1763 of Bologna is to capture mono-aural, binaural and impulse response data. By employing this technique, already been described in [7], it is possible to obtain the spatial information of any performing arts space.

During the measurement campaign executed in Teatro 1763, a set of RIRs has been measured at each angular position by using three different types of microphones (i.e. B-format, a binaural dummy head and two cardioids in ORTF configuration) [8]. The ORTF configuration has been used to recording stereo signals obtained by two cardioid microphones spaced 170 mm and diverging each other by 110°. The B-format microphone, which was introduced by M. Gerzon [1], is able to capture 4 signals: one omnidirectional (pressure) and three with polar patterns, called figure-of-eight, oriented along the three axes X, Y, Z. These three capsules allow to obtain a signal proportional to the three components of the particle velocity vector. A combination of the results obtained by applying this measurement technique is able to derive all the multi-channel formats (i.e. 5.1, 7.1, 10.2, etc.).

2.3 MIMO method for RIRs employed in Teatro Sociale of Gualtieri

With the continuous innovation of technology, the methodology discussed in Section 2.2 is considered very slow, not only for the microphone setup being much tedious for a correct installation but also for the combination of the information coming from the three microphone systems. As such, an easier and more powerful measurement system has been developed.

The innovative equipment is composed of a multi-channel microphone (i.e. em32 Eigenmike®), that is based on a spherical microphone array which contains 32 capsules mounted on a spherical surface having an 80mm diameter. It also contains preamplifiers, analogue to digital (A/D) converters, and an audio-over-ethernet chipset. In this way, it becomes simpler to get measurements of multi-channel IRs, considering also a better spatial resolution. Although the producer (i.e. MH Acoustics) developed already a new generation of spherical microphone array equipped with 64 capsules (i.e. em64 Eigenmike®) it was not possible to test this latest kit because not available on the market at the time of measurements; herein is the impossibility to compare its functionalities with the existing applications.

The multi-channel microphone system has been initially developed for real-time recording and broadcasting applications, in order to extract any arbitrary directivity of virtual microphones from real microphone arrays [9], but now it is well known in the acoustics research.

The microphone em32 is capable of capturing any real-time variable directivity in order to follow actors/musicians during the performance. The real-time variable directivity is possible by using a mouse/joystick, able to change the sharpness of the patterns by zooming in/out. The pattern is determined by using cardioid microphones of various orders, according to equation (1).

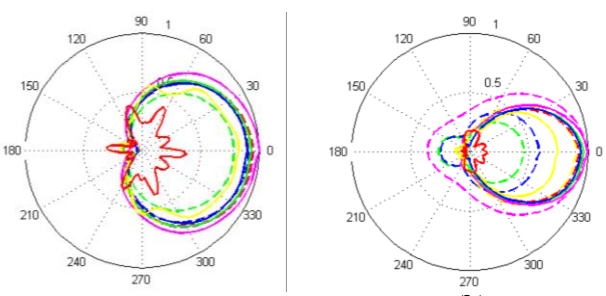
$$Q_n(\vartheta, \varphi) = |0.5 + 0.5 \cdot \cos(\vartheta) \cdot \cos(\varphi)|^n \qquad (1)$$

where *n* represents the directivity order of the microphone.

The signals recorded by the em32, analysed in a post-processing phase by using Matlab application, can generate 32 virtual microphones [10, 11], which could be subjectively perceived [12, 13] having any directivity patterns by combining the directions of the 32 capsules located on the spherical surface [14-16], eventually adding nonlinear effects [17].

In this way, the 3D sound environment can be spatially sampled with an almost constant angular amplitude [18]. The spatial sampling resulting from the measurements can therefore be considered as a PCM sampling, whereas the traditional spherical harmonics sampling by using a high order Ambisonic (HOA) system can be ordered as a spatial Fourier sampling [19, 20].

Figure 1 shows two polar patterns related to virtual cardioid microphones of 1st and 4th order Ambisonics, obtained by applying the FIR filters into the analysis process [20].



(**a**) (**b**)

Figure 1: Directivity patterns of a virtual microphone : (a) 1st order, (b) 4th order Ambisonic.

3 Two cases of historical theatres

3.1 Teatro 1763, Bologna, Italy

Historical Background

The Teatro 1763 in Bologna is a small theatre inside the historical Villa Aldrovandi Mazzacorati and it was inaugurated on 24th September 1763. It was built as a private theatre of Aldrovandi family. The interior decoration of the theatre was entirely organized by Count Gian Francesco Aldrovandi. The paintings were commissioned to Filippo Balugani while the backdrop on stage was assigned to Antonio Basoli in 1810 [21]. The audience area has a rectangular shape and is characterized by the presence of twenty-four plaster telamones and caryatids, which support two continuous "U"-shaped balconies. The main spaces characterising the Teatro 1763 are the following: backstage, raised stage, tooling room, foyer with double access from outside and another entrance connecting the theatre with the internal halls. It has a capacity of 80 seats, but originally chairs and balconies could accommodate till 200 attendees. With the extinction of Aldrovandi dynasty, the ownership of the Villa passed to Giuseppe Mazzacorati in 1828 first and other families until the property in 1928 was ceded to fascist soldiers who made of it a summer camp for children [21].

Figure 2: View of the main hall of Teatro 1763.

Although the entire building fell into disuse for many years, the theatre itself was not damaged even during the Second World War, keeping preserved its original shape. Moreover, it still retains some original elements including canvas backdrop, ten sceneries on stage and many chairs [22]. Figure 2 gives a good view of how the theatre has been preserved with the original features and furniture [22].

Table 1 summarises the architectural features of the Teatro 1763.

Table 1: Architectural characteristic of Teatro 1763.

Description	Data
Shape of the main hall	Shoe-box
Levels of balconies	Two
Type of roof	Wood and Flat
Initial capacity (n. seats)	200
Actual capacity (n. seats)	80
Volume of the main hall (m^3)	Approx. 1150

Acoustical measurements

The acoustical measurements were undertaken with the following equipment:

- Sound source: equalized dodecahedron;
- Microphones:
  - Dummy head (Sennheiser);
  - B-Format microphone (Soundfield MK-v);
- Personal Computer connected to a loudspeaker and to receivers.

The excitation signal to measure the RIR was an exponential sine sweep (ESS), having a frequency range set between 40 Hz and 20 kHz. The sound source has been located on the stage while all microphones were moved to different positions throughout the stalls and the first gallery, in order to better represent all the audience areas, as indicated in Figure 3.

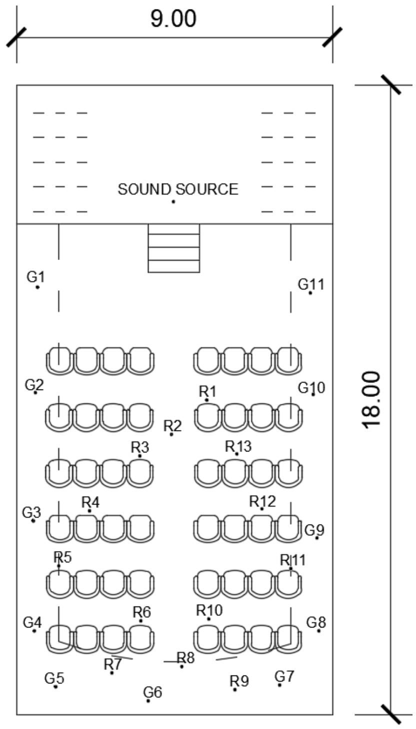


Figure 3: Source and receiver positions (R1-R13: receivers in the stalls; G1-G11: receivers in the first gallery) in Teatro 1763 of Bologna. The main dimensions of the theatre are 18 x 9x h7 meter.

Results of measurements undertaken inside Teatro 1763 of Bologna

The recorded ESS signals have been processed by using the plugin Aurora suitable for Audition. The results of the data analysis represent the main acoustical parameters, presented in the octave bands between 125 Hz and 8 kHz, as shown in the following figures. The values are to be considered as the average results of all the measurement positions.

Figure 4 indicates that the parameters EDT and T_{20} are very comparable. The results give an average value of approximately 1.2s for low-mid frequency bands, with a small shortfall (till 0.9s) for 2 kHz and 4 kHz. The graph indicates a good time response for both speech and music, with a uniform balance across all the spectrum.

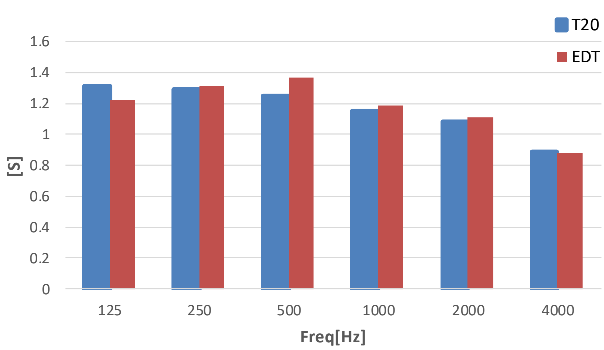


Figure 4: Measured results of Reverberation Time.

Figure 5 and 6 show respectively the averaged values of C_{50} and C_{80} of all the receivers as a function of frequency.

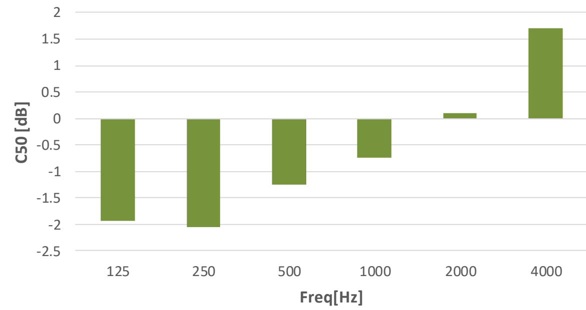


Figure 5: Measured results of Clarity Index (C_{50}).

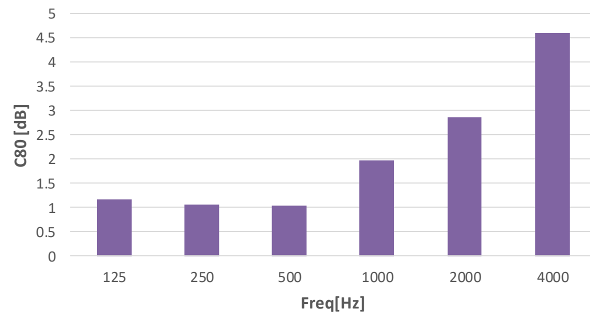


Figure 6: Measured results of Clarity Index (C_{80}).

The clarity of speech (C_{50}) resulted to be between -2 dB and+2 dB, which is a very good range. The clarity of music (C_{80}) resulted slightly high (i.e. 4.5 dB) only at 4 kHz, while for the other frequency bands the range is between 1 dB and 3 dB, which are also good values.

The averaged value of definition (D_{50}), as shown in Figure 7, resulted between 40% and 50% for low-mid frequencies, which is considered the minimum acceptable percentage for both good listening and speech comprehension. Values more than 50% were found at high frequencies, which is quite common for rooms of similar volume dimension.

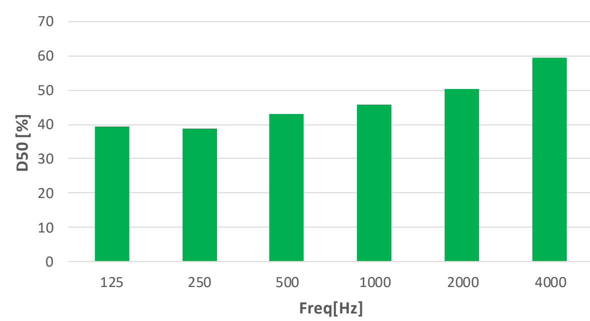


Figure 7: Measured results of Definition

Beside the acoustical parameters, which could be obtained even with a common mono-aural microphone, the utilisation of the B-format microphone (i.e. Soundfield) can be considered one of the first approach used to gather the detection-of-arrival of the sound reflections after hitting the boundaries of the room. The acoustical maps obtained after data processing are rendered with a panoramic view of the ambient combined with the overlapped sound rays, represented in the function of relative sound intensity.

Figure 8 shows an alternative arrangement of how the acoustic study of a room can be implemented by representing a visual map of the sound rays. In particular, the moving circle on the top right corner of Fig. 8, indicates the direction of arrival of the sound ray, which is also represented on the panoramic view on the left window, that shows which construction element has been hit by the sound wave. Furthermore, the variable diameter of the green circle is directly proportional to the sound energy on the room's surface, while its position follows the movement of the sound signal inside the theatre.

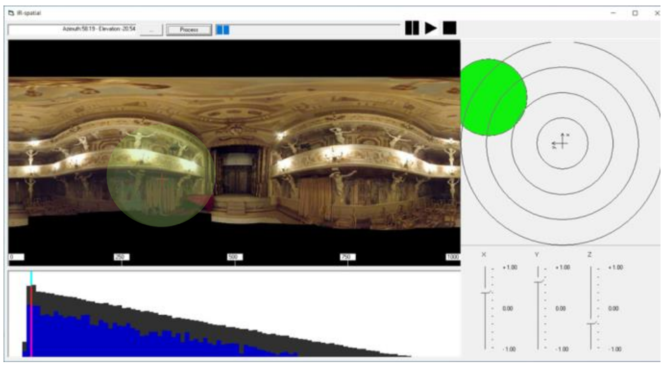


Figure 8: Directional map representing the reflections bounced on the boundaries of the theatre. Note that the x-axis is oriented towards the stage.

3.2 Teatro Sociale, Gualtieri, Italy

Historical Background

Teatro Sociale of Gualtieri was realized inside the Bentivoglio palace, a building-fortress built during the 16th century and promoted by Duke Alfonso II d'Este [23]. During the 17th century, the palace was disfigured and partially destroyed, especially when it became a military barrack during the civil wars. In 1750 the palace was bought by the city hall of Gualtieri and it became a municipal property [23]. Among the civil activities (e.g. slaughtering, wheat storing) hosted inside the palace, the population promoted also the development of performing arts and the realization of a small theatre, that was designed by the architect G. B. Fattori [23].

The theatre was planned to have a layout in horseshoe shape with three orders of balconies in baroque style. The initial dimensions were restrained if considered that the volume of the main hall was 11×8×6 meters (L×W×H), and the stage was extracted by a stairwell. As such, the theatre had been living always with the problem of craving more space to facilitate the arrangement of seats more comfortably [24].

During the first decade of the 21st century, the necessity of restoration works brought to the idea of rotating the original functions of the room in order to do not destroy the authenticity of the historical decorations [24]. Therefore, the seats have been planned to be organized into the space of the old stage, while the actors would be standing onto the area previously dedicated to the audience, as shown in Figure 9.

Figure 9: View of the Teatro Sociale of Gualtieri.

Table 2 summarises the architectural features of the Teatro Sociale of Gualtieri

Table 2: Architectural characteristic of Teatro Sociale of Gualtieri.

Description	Data
Shape of the main hall	Horseshoe
Levels of balconies	Three
Type of roof	Bricks and Arched
Initial capacity (n. seats)	120
Actual capacity (n. seats)	300
Volume of the main hall (m^3)	Approx. 1050

Acoustical measurements

The acoustical measurements were undertaken with the following equipment:

- Sound source: spherical array of loudspeaker (i.e. prototype realized by University of Parma) [6];
- Microphone: spherical array multichannel (i.e. em32 Eigenmike®);
- Personal Computer connected to the loudspeaker and the receiver.

The excitation signal to measure the RIR was an exponential sine sweep (ESS), having a frequency range set between 40 Hz and 20 kHz. Figure 10 shows that the sound source has been located in three positions while the microphone has been moved to six positions throughout the audience area.

Results of measurements undertaken inside Teatro Sociali of Gualtieri – Standard representation

The results shown in the following figures are to be considered as the average results of all the measurement positions, that are presented in the octave bands between 125 Hz and 8 kHz.

The averaged result of T_{20} across all the spectrum, as shown in Figure 11, is approximately 1.2s which is a good value for both speech understanding and listening to music. The EDT curve has a downwards trend, which is 1.8s at 125 Hz and having values similar to the T_{20} for high frequencies. This effect is mainly

Figure 10: Source and receiver position inside Teatro Sociale of Gualtieri.

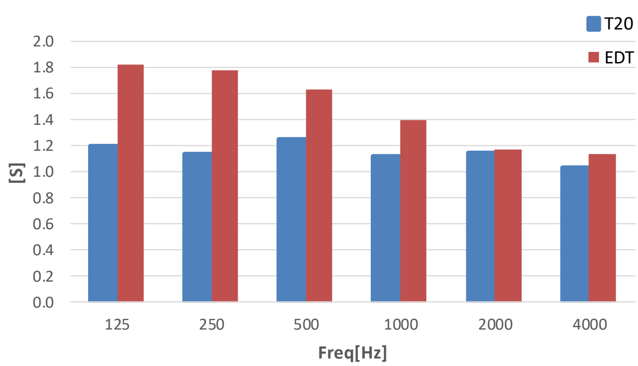


Figure 11: Measured results of Reverberation Time

due to the reversing position of stage and audience areas because nowadays the sitting area is in place of the previous scenic tower, where the vertical surfaces, important for early reflections, are more distant than what it would be in the horseshoe hall.

Figure 12 and 13 show, respectively, the averaged values of C_{50} and C_{80} of all the receivers as a function of frequency.

The clarity of speech (C_{50}) resulted to be between -2 dB and +2 dB across all the spectrum, which is a very good range, except for 125 Hz, showing a value of 4.5 dB, which is slightly high but not disrupting for a speech understanding.

Overall, the values related to the clarity of music (C_{80}) have a good range between 0 dB and 5 dB, although the curve is dissimilar across all the spectrum. The C_{80} shows values around 0 dB for 250 Hz and 500 Hz, and around 5 dB for 125 Hz and 2 kHz.

The peak at 125 Hz, resulted for both C_{50} and C_{80}, is mainly due to the booming effect provoked by the volume of the scenic tower, whereas the audience stands for this particular theatre. While the peak at 2 kHz is owed to the hard material on floor and walls (i.e. bricks and stone), reflecting the most directive sound waves at this specific frequency band.

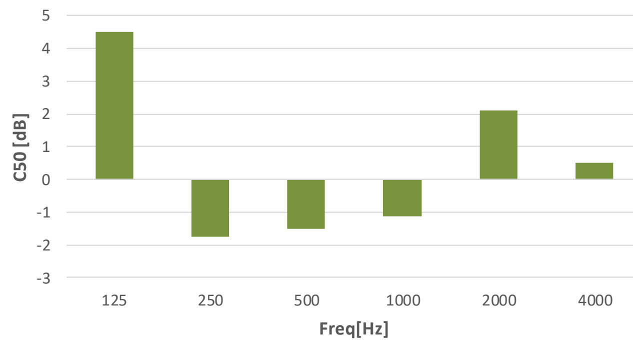


Figure 12: Measured results of Clarity Index (C_{50}).

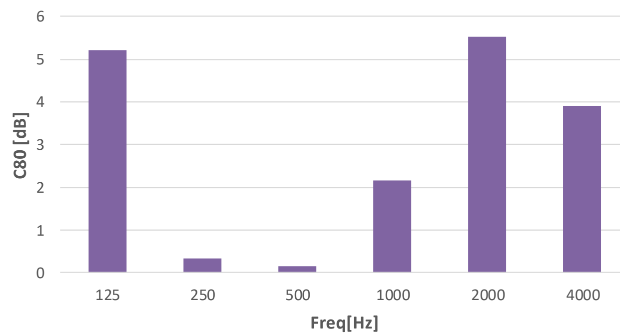


Figure 13: Measured results of Clarity Index (C_{80}).

The parameter of definition (D_{50}), as shown in Figure 14m resulted poor at low frequencies (i.e. 125 Hz), nearly acceptable at mid frequencies (i.e. between 250 Hz and 1 kHz) with a small shortfall and acceptable at high frequencies. This subdivision in three different steps reflects the considerations previously discussed. In particular, the low frequencies feel the lack of definition due to the booming effect, which occurs when the reverberant field is predominant than the direct sound, which is what is occurring in an empty scenic tower at whole height, having reflecting materials on walls and floors. If this result can be considered a worth on the musical side, by creating a fusion of musical notes, it is seen uncomfortable for speech understanding.

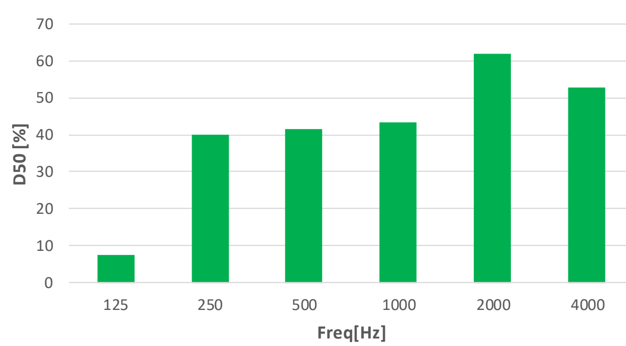


Figure 14: Measured results of Definition

The RIR data gathered by the measurements [5] undertaken inside the Teatro Sociale can be processed in another way, in order to obtain added outcomes in addition to the standard representation of the acoustical parameters. By using a spherical array 32-channel microphone (i.e. em32

Eigenmike®), instead of a 4-channel B-format microphone, the acoustical maps can be developed. In particular, the more innovative graphical analysis is able to show the spatial distribution of the energy emitted by the sound source throughout coloured contour levels in the function of the sound intensity, whereas with the previous technique it was shown by the diameter of a green circle.

The 3D audio playback is obtained by extracting a set of virtual microphones from the IR data. The directivity of each virtual microphone is obtained by solving a matrix of linear and time-invariant FIR filters, (i.e. a process commonly called beamforming) [10].

The overall result is a coloured video which renders a sound map overlapped to a 360° panoramic view. A screenshot of such rendering is shown in Figure 14 below.

Figure 15 shows the implemented representation of what has been explained previously in relation to the Teatro 1763. In particular, with the increase of the number of channels, the sound pressure level, having different ray energy, is represented by an iris colour scale. The scale of values represents the difference in intensity, not the absolute values. The sound waves having more energy are represented with red and warm colours, while the blue-violet colours indicate a poor energy sound wave. Figure 15 shows the reflections hitting the sidewalls of the proscenium arch of the Teatro Sociale of Gualtieri.

Figure 15: Example of a graphical analysis showing strong reflections hitting the sidewalls of the proscenium. The scale of values represents the difference in intensity, not the absolute values.

The impulse response of the multichannel microphone array has been captured by using incident wavefronts from a large number of characterization directions, which are uniformly distributed over a spherical surface by a spatial oversampling owed to a 32-channel microphone [9], as already described in Section 2.3.

4 Discussion

The speedup of progress related to science and technology during the last few decades moved the industry towards the improvement of the digitalization.

Over this background, one of the scopes of Sipario project, a research project funded by the Italian region Emilia Romagna, is the virtual reconstruction of 3D audio and panoramic view of real musical events performed inside historical theatres and concert halls [25]. In order to achieve this purpose, the acoustic RIR measurements can be advanced by using a new generation of equipment, capable of giving back both the results of the acoustical parameters and the information related to the spatial control of the sound propagation.

It should be considered that the improvement of results related to the reconstruction of auralization is mainly related to the usage of equipment typology, which shall satisfy the ever-increasing needs of faithfully representing the reality with the virtual devices.

This paper has shown a few steps of how the technology progression has repercussions on the acoustical results. As the standard equipment composed of an omnidirectional sound source and an omnidirectional microphone are sufficient to describe the acoustical parameters of a room, the implementation by using multi-channel equipment can offer further outcomes to be considered as an added value (and not a substitution) of the traditional representation by graphs.

The passage from a 4-channel to a 32-channel microphone allows obtaining a more detailed and refined rendering in terms of directivity patterns. At the time of measurements, a 64-channel microphone was not yet available on the market, which would have been a good case-study to complete the comparison described in this paper. With the utilisation of the em64 Eigenmike® in the next measurement campaigns, the authors expect that the double number of capsules (i.e. 64, instead of 32) would give more highly directive virtual microphones, having beam width sharper than what obtained with 32 channels.

5 Conclusion and further research

The development of RIR analysis combined with the Multiple Input Multiple Output (MIMO) technique determines the direction where the auralization is addressed nowadays. Although the utilization of multichannel spherical arrays of both microphone and loudspeaker is still experimental, the demand of a faithful reproduction of a 3D audio playback of artistical venues is increased considerably, especially during the lockdown period of Covid-19 pandemic.

Other than reproducing the acoustical features of historical architecture, one of the targets to be achieved by Sipario project is to address people, that never attended live performances, to appreciate performing arts. As such, Sipario is widening the already described acoustical techniques in order to reproduce a 3D soundscape measured into theatres by using inexpensive devices (e.g. a set of head-mounted display HMD plus headphones or Google Cardboard visor, smartphones, etc.) and keeping in the meanwhile the high quality of the recordings [26]. In addition, an immersive listening experience can offer unique feelings when a 360° panoramic video allows to virtually visit such historical buildings, most of them protected by international organizations (e.g. Unesco), in order to preserve them to the future generations.

Further research studies will be focusing on a double number of multichannel source and a multi-channel receiver. A customized construction of a sound source equipped with 64 transducers (always characterized by a spherical array), having the same number of capsules of a new microphone (i.e. em64 Eigenmike®) will be the development of the principles already discussed. The expected results would be a sharper directivity of such virtual microphones and virtual sound sources, capable of rendering more realistically the audio-visual environment.

Acknowledgments

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VARIATIONS IN THE ACOUSTIC MEASUREMENT OF EARBUD EARPHONES IN AN ANECHOIC CHAMBER DUE TO CHANGES IN THE EARPHONE PLACEMENT IN EAR CONCHA

S. J. Pawar*[1], Y. C. Liu†[2] and Jin H. Huang‡[3]
[1]Department of Applied Mechanics, Motilal Nehru National Institute of Technology Allahabad,Prayagraj INDIA,
[2]Bachelor's Program in Precision System Design, Feng Chia University, Taichung, Taiwan, Republic of China,
[3]Department of Mechanical and Computer-Aided Engineering, Feng Chia University, Taichung, Taiwan, Republic of China,

Résumé

La croissance des produits électroniques grand public, encouragés par les innovations, a stimulé le développement persistant des écouteurs pour une reproduction sonore de haute qualité. L'écouteur bouton est situé dans le pavillon de l'oreille humaine en face du conduit auditif. Le placement des écouteurs dans le pavillon de l'oreille joue un rôle remarquable dans la réponse du niveau de pression acoustique d'un écouteur. Dans cette étude, dix écouteurs ont été testés pour la réponse en fréquence et la distorsion harmonique totale en utilisant un simulateur de tête et de torse dans une chambre anéchoïque. Trois positions et deux orientations d'écouteurs dans le pavillon de l'oreille ont été identifiées pour la mesure. Sur la base des réponses de tous les écouteurs à toutes les orientations et positions, il est conclu qu'il existe une variation de la réponse en fréquence et de la distorsion harmonique totale. Même si la variation est de faible ampleur, son effet sur la perception du son, l'exposition au son et le seuil d'audition est phénoménal. Sur la base de la proposition présentée dans ce travail et de l'exposition sonore quotidienne sûre, il a été suggéré que la variation de la réponse en fréquence affecte la sonorité perçue de la musique/du son et peut provoquer des différences significatives dans la limite d'exposition sonore quotidienne pour un être humain.

Mots clefs : écouteur bouton, réponse en fréquence, oreille humaine, niveau de pression acoustique, distorsion harmonique totale

Abstract

The growth of consumer electronic products is encouraged by innovations and has stimulated the persistent development of earphones for high-quality sound reproduction. Earbud earphone is located in the concha of the human ear facing an ear-canal. The placement of earphones in the concha plays a remarkable role in the sound pressure level response of an earphone. In this study, ten earphones were tested for frequency response and total harmonic distortion using head and torso simulator in an anechoic chamber. Three positions and two orientations of earphones in the concha were identified for measurement. Based on the responses of all earphones at all orientations and positions, it is concluded that there is a variation in the frequency response and total harmonic distortion. Even though the variation is small in magnitude, its effect on sound perception, sound exposure, and the hearing threshold is phenomenal. Based on the proposition presented in this work and the safe daily sound exposure, it has been determined that the variation in the frequency response affects the perceived loudness of sound and can cause significant differences in the daily sound exposure limit for a human being.

Keywords: earbud earphone, frequency response, human ear, sound pressure level, total harmonic distortion

1 Introduction

The growth of 4C products (i.e., computer, communication, consumer electronics, and car electronics), or the consumer electronic products, has encouraged new developments in the electroacoustic community worldwide. The relentless evolution of earphone has stimulated a cache of innovations in the field of electroacoustic transducers. The earphone is intended not only for the delivery of high-quality sound but is required to be stylish, slim, portable, and aesthetic. High-fidelity sound reproduction over a wide frequency range has explored "Research Avenue" in earphone design and development for the electroacoustic community. The typical earbud earphone (EE) rests within the concha (Figure 1) facing an ear-canal [1]. The EE is subjected to-sound leakage across its interface with concha due to the human ear anatomy. The frequency response (sound pressure level (SPL)) of EE depends on the parameters associated with both the earphone and ear. The earphone parameters involve a miniature loudspeaker, earphone size, earphone shape, earphone enclosure volume, vent, and sound holes in the enclosure. The parameters associated with an ear are an ear-canal and its transfer function, shape & size of the concha, and leakage across earphone-concha interface. The placement of an earphone in the concha plays a significant role in the earphone's SPL response and total harmonic distortion (THD). The SPL, the localized pressure fluctuations created by sound-producing device over the atmospheric pressure attributes to the range of frequencies that the sound-producing device can reproduce. The THD is owed to the loudspeaker nonlinearity that generates additional signal components from the loudspeaker and associ-

* sjpawar@mnnit.ac.in
† ycliu@ fcu.edu.tw
‡ jhhuang@fcu.edu.tw

ated electronic hardware, which causes output signal distortion. Thus, the THD may deteriorate the sound quality of an earphone.

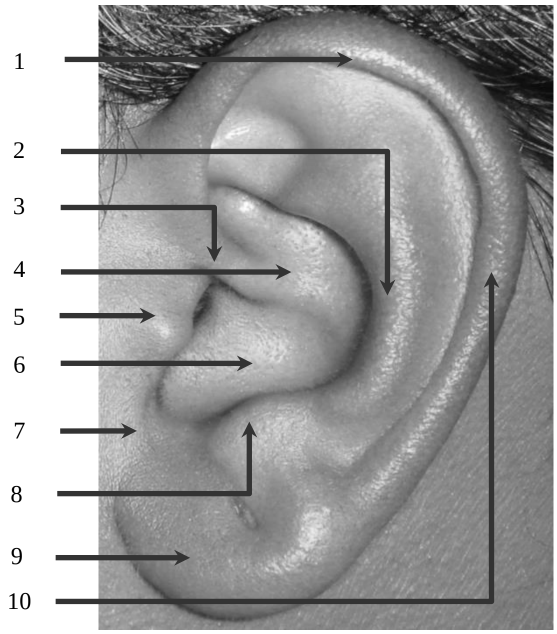

Figure 1: Anatomy of an external ear.

An acoustic performance estimation and measurement of telecommunication equipment by an artificial ear has been given in ITU-T Recommendations P.57 [1]. B&K developed a Head and Torso Simulator (HATS), known as Type 4128 [2], for an in-situ acoustic evaluation and performance estimation of audio products. An International Electrotechnical Commission (IEC) coupler (IEC-60711) [3] and B&K measurement microphone are housed in the HATS. Wojcik and Cardinal (1999) [4] discussed uncertainties in the measurement by the HATS. Riederer and Niska (2002) [5] carried out measurement and simulation of 3D sound with insert headphones. The ear-tip of earphone allows the exact positioning of the earphone in the concha, which results in the attenuation of background noise 15-20 dBSPL as reported. Ćirić and Hammershøi (2006) [6] addressed the measurement of earphones by ear using a standard coupler and found that individual ears have detected significantly different levels of SPL. Tikander (2007) [7] provided a lumped element model to simulate the sound of transmission path from the surrounding environment into the ear-canal. Additionally, an air leakage due to the cloth (sponge) had been modeled. In an attempt to calibrate headphones and earphones by KEMAR for psychoacoustic experimentation, Zhiwen *et al.* (2009) [8] reported a significant change of sound pressure on the tympanic membrane due to small change in the location of an earphone in the concha. Liu (2008) [9] explained the ergonomic design and development of ear-related products by providing anthropometric dimensions of an outer ear. Erber (1968) [10] investigated the influence of an outer ear configuration on the acoustic stimulus by a supra-aural headphone on the tympanic membrane. Zwislocki *et al.* (1988) [11] reported unpredictability in the audiometric applications of an earphone due to the variability associated with an acoustic coupling between the sound source and an eardrum. Kulkarni and Colburn (2000) [12] pointed out that the performance of supra-aural headphones varies with the positioning of the headphone cushion during normal usage by KEMAR measurements. A significant effect of middle ear pathologies on the sound pressure variation in the ear-canal has been indicated by Voss *et al.* (2000) [13]. Ruiz *et al.* (2005) [14] reported issues during the measurement of electro-acoustic instruments during the calibration of audiometric and psychoacoustic tests. For uncertainty in the response of circum-aural earphones, The effects of temperature and placement were quantified by measurements. The sound leaks to the surrounding, from the rear side of EE in two ways, first, through the soundhole and second from the interface of EE casing and concha surface. Due to the leakage of the sound, the SPL detected by eardrum changes [15]. The modeling and measurement of EE has been carried out in our previous publication [16]. The field studies [17-19] were done for investigating the use of portable audio devices and the hearing health of customers.

Liu (2008) [9] performed an extensive data collection and analysis for understanding the human ear anthropometry for effective design of ear-related products. It is evident that the anthropometric dimensions of the outer ear for different demographic data, including gender, age, etc. plays a significant role in mass customization and collaborative ear-related product design. Three dimensions of the outer ear (earhole length (L_a), ear connection length (L_b), and pinna length (L_c)) were decided (Figure 2) as significant. Two hundred subjects (20-59 years of age) were grouped into four age groups for ear dimensions determination by the superimposed grid photographic technique. The outer ear plays a prime role in the collection of sound from the environment and transmission of same to the middle ear. The outer ear collects the sound and transmits it to the tympanic membrane (diaphragm) through the auditory canal (ear-canal).

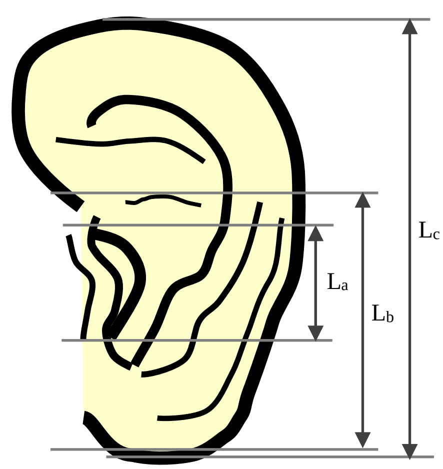

Figure 2: Three critical dimensions of human ear [9].

The average values of ear dimensions were measured and L_a was found to be larger in males (15.6 mm vs. 14.5 mm), also L_b is appreciably higher in males (47.5 mm vs. 42.2 mm), and L_c is also significantly similarly larger in males (58.4 mm vs. 53.9 mm). These facts establish gender dependence on the dimensions, however, show no significant difference across different age groups. The dimension analysis of both the ears show a strong correlation between the right and left ears, revealing their asymmetry. It is concluded that the right ear had larger dimensions than the left ear.

Erber (1968) [10] reported that mean hearing sensitivity for young subjects differ. Young females of 18-24 years of age demonstrate better hearing than males of that age. There have been anatomical dissimilarities of auditory systems (viz. skull, pinna, ear-canal dimensions, quantity, and quality of external hair) and hair along with cerumen content of the ear-canal. Besides, studies reveal that acoustic stimulus created by earphones at the tympanic membrane can be affected by factors like voltage applied to the earphone, force applied on the earphone, earphone cushion-pinna seal, ear-canal volume, earphone and cushion type, etc. Middle ear pathologies alter the impedance of the middle ear, and also every deviation in the anthropometric dimension of the ear can change the impedance. Lee *et al.* (2016) [20] carried out detailed anthropometric dimensions of the outer ear for the design of ear-related products. The outer ear consists of three main parts (pinna, concha, and external auditory canal). Figures 3 (a-c) shows some significant anthropometric dimensions of the human ear, focusing mainly on the earbud earphone as L_{aa} = Cavum concha length, L_{ab} = Cavum concha width (also L_{bb}), L_{ac} = Centre of concha to anterior cymba concha length, L_{ba} = Ear-canal length, L_{ca} = Cavum concha depth, L_{cb} = Ear-canal depth (also L_{cd}), and L_{cc} = Pinna flare angle.

In confirmation with the anatomy of an average human ear and according to ITU-T recommendations, the diameter of EE should be less than 25 mm for proper fitting in the concha cavity. The diameter of earphones available in the market varies from 12-20 mm. The miniature-loudspeaker (Figure 4 (a)) is housed in an aesthetically shaped casing of earphone (Figure 4 (b)). The EE generates sound from the front and back. Also, there are two sound leakages from EE to its backside. One through the vent holes in the under-yoke of the loudspeaker to earphone cavity which further leaks to the backside via the sound-hole in an earphone cover. Another sound leakage is from the rear side of an earphone through an earphone circumference and the concha interface.

The B & K Type 4128 is typical HATS, it consists of an artificial head mounted on a torso extending to the waist. It lets an accurate simulation of an acoustic field around a human head and a torso for airborne acoustic measurements. The HATS consists of a removable silicone rubber pinna, an occluded ear-simulator, and a 1/2" microphone with a preamplifier. The placement of EE in the pinna (concha cavity) is in definite relation to the ear reference point (ERP) and an ear-canal entrance point (EEP) [1]. A schematic of B & K HATS with EE resting in a concha cavity is given in Figure 4 (c). In a human ear, EE rests against the cavum (concha) and is supported by the crus helias, tragus, and anti-tragus (Figure 1). Besides, the tragal notch assists in the placement

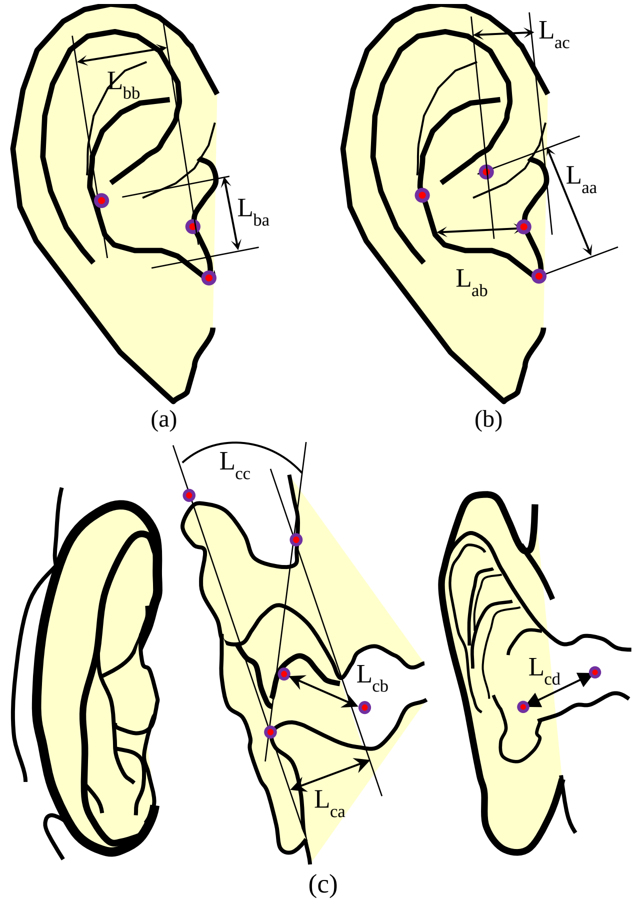

Figure 3: Some significant anthropometric dimensions of human ear [20].

of EE so that it should not loose during regular uses. Due to the variations in the anatomy of a pinna, it is difficult and impracticable to fit EE in the concha cavity perfectly. As a result, some sound leaks through the EE circumference and concha interface (Figure 4 (c)), shown by arrows from the top and bottom of EE. However, majority of the sound is directed towards an ear-canal opening and reaches to the pinna external cavity. Moreover, the sound goes to the pinna circular cavity and finally enters the IEC-60711 coupler and is detected by the microphone housed in IEC coupler.

The SPL or the frequency response of a loudspeaker is a vital characteristic to quantify the behavior of loudspeaker. In a perfect condition, the curve should be flat over the working range of a loudspeaker. The THD of a signal is a measurement of the harmonic distortion in an output which is the ratio of sum of the powers of all harmonic frequency components to the power of fundamental frequency. The THD characterizes the linearity of audio system, loudspeaker, amplifier, microphone, etc. Generally, the THD is expressed either in decibel or in percentage. It is nonlinearity, resulting in addition of unwanted signals to the input signal that is harmonically related to it. Hence the spectrum of the output shows some added frequency components at 2x, 3x, 4x, 5x, and so on of an original signal.

Klippel, in a series of papers [21-24], discussed the nonlinear behavior of loudspeakers. The loudspeaker generates a nonlinear signal component in the output along with the orig-

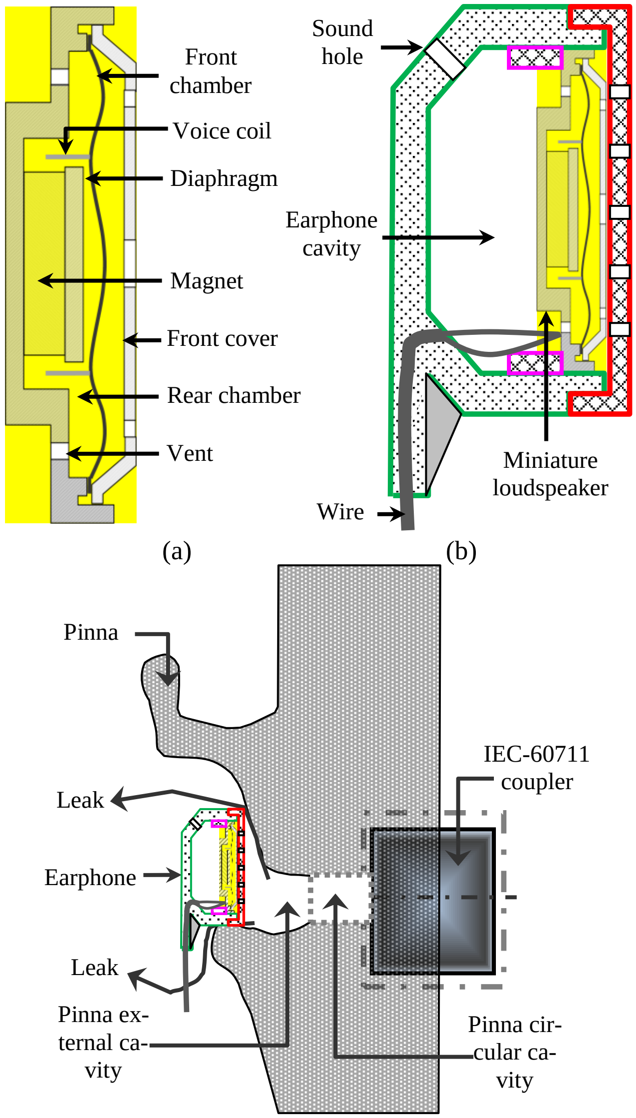

Figure 4: Schematic of (a) Miniature loudspeaker, (b) Earbud earphone, and (c) B&K HATS with earphone in concha.

inal signal when driven at high input level. In most cases, the nonlinear signal components are unwanted; but, are inherent due to nonlinearity of the electro-dynamic loudspeaker and cannot be avoided. Motor and suspension nonlinearities are two dominant causes of loudspeaker nonlinearities. The distortions can also be categorized as a regular and irregular. The nonlinear properties of loudspeaker design cause regular distortions and are usually dominating 2^{nd} to 5^{th} harmonics as well as THD [25]. Irregular distortions are due to defects, manufacturing process artifacts, aging, and other external impacts (overload, climate, etc.) during the life cycle of the loudspeaker. A rubbing voice coil, buzzing parts, loose particles in the gap, and air leaks are some common loudspeaker defects. The regular distortions are significant at low frequency; and, irregular distortions are usually broadband. Much smaller amplitude irregular distortions are masked by the lower order regular distortions. In our earlier efforts [26, 27], an effect of the nonlinear suspension stiffness on the SPL and THD has been simulated, experimented, and validated for a circular and an elliptical miniature loudspeaker, respectively. Analogously, an effect of a nonlinear force factor on the SPL and THD of a circular and an elliptical miniature loudspeaker has also been simulated, experimented, and validated by our group [28, 29], respectively.

In continuation with the various field studies [17-19], an extensive logistic about human ear, human hearing, etc. were documented. Enormous capabilities of the human ear have been explored in terms of the frequency range covered, sound pressure sustained, and sound energy handled. The remarkable abilities of the hearing system have been highlighted, along with challenges and risks [30]. Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) in 2008 gave a detailed report and advisory advised on the potential health risks of exposure to noise from personal music players and mobile phones. The inability to hear sounds below certain thresholds is the most common form of hearing impairment. It is reported that exposure to excessive noise is a significant cause of hearing disorder worldwide. Nearly 16% of the hearing loss disabilities in adults are due to occupational noise. The personal music players now play not only music but provide podcasts of various activities, which are listened through ear-bud and insert types of EEs producing a range of maximum SPL around 80-115 dB(A). Remarkably, the difference in EE type may increase the SPL by 7-9 dB, specifically, the ear-bud creates the highest levels of about 120 dB(A) in the worst-case scenario it is caused by the insertion depth of the ear-bud in the ear-canal [31]. World Health Organization in 2015 [32] published a review related to the hearing loss due to recreational exposure to loud sounds. The report gave a comprehensive account of human hearing and the effect of noise. Additionally, the treatment of the noise-induced hearing loss is suggested along with prevention. Strategies are proposed by the use of legislation, social media, intervention, education conservation, etc.

Based on the variations of anthropometric dimensions of the human ear, the sound perception by different individuals from the same earphone shall be different. The effect of various factors like earphone shape, earphone size, earphone position in the concha, earphone orientation in the concha, earphone circumference and concha surface seal, earphone force on concha surface, etc. are also prominent. This study proposes and establishes that the sound perception by individuals from the same earphone shall be dissimilar due to different orientations and positions of EE in the concha. Alongside, the sound impression by the right and left ear of the same individual shall also differ. The study infers that the prolonged usages of EE may change the orientation, position, force, earphone circumference and concha surface seal, etc. which may cause variation in the SPL generated across the tympanic membrane.

2 Materials and Method

As an extension of our previous work [15], two distinct EE orientations have been identified (Figure 5) in this work. At position 1, the earphone's front surface is placed directly against the concha bottom surface and is supported along the circumference by the tragus, anti-tragus, and crus helias. The tragus sometimes covers the EE, based on the anatomy of the ear. As shown in Figure 5, positions 2 and 3 are similar to position 1; but differ slightly due to the placement of EE wire. The earphone wire is located along the tragal notch, anti-tragus, and an anterior notch for positions 1, 2, and 3, respectively. At position 1, the anthropometric notch of ear assists in perfect fit of the earphone with minimum sound leakage and least pinna external cavity volume. At position 2, due to projection of anti tragus, wire of the earphone gets lifted and extra volume is created in the pinna external cavity, along with the possibility of a higher sound leakage through the tragal notch. Similarly, at position 3, anterior notch assists the earphone wire placement in different ways, which is dependent on the anthropometry of the ear. This position affects sound leakage and pinna external cavity volume. Two different orientations of earphones are also identified as given in Figure 5. In orientation 1, earphone is directly supported against the concha bottom surface of the concha. On the contrary, the earphone is inclined (roughly 10-45° depending on the anatomy of a human ear) against the concha bottom surface in orientation 2 so that the front surface of the earphone faces the auditory canal opening. Based on the orientations mentioned above, a direct exposure of EE to the ear-canal opening varies, which implies different pinna external cavity shapes and volume, different leakage levels, and different positions of the sound sources about ERP. Hence, it is anticipated that there may be variation in SPL and THD responses of earphones when the position and orientation of EE are changed.

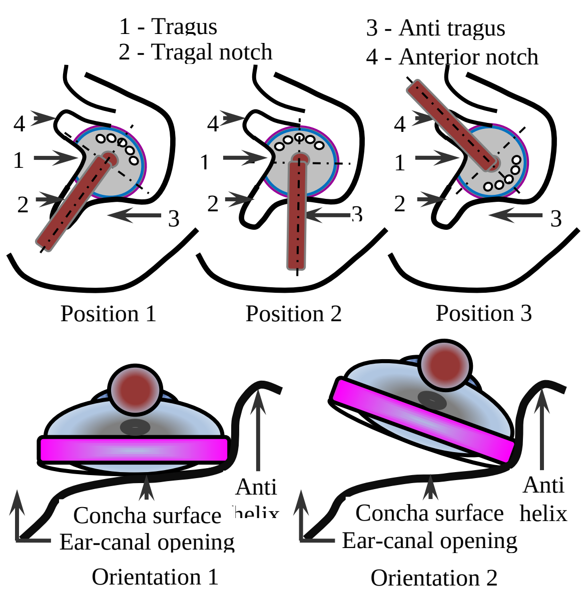

Figure 5: Schematic of earphone placement in concha for measurement.

The schema of the anechoic chamber measurement of frequency response and THD of EE is given in Figure 6. An earphone is positioned in the concha of the HATS. The software (SoundCheck® 8.1, Listen Inc. Boston, MA, USA) generates a test signal for the earphone via an amplifier. The microphone of the IEC-60711 coupler receives the sound pressure generated by the earphone and finally communicates it back to the software for further processing. In this study, the measurements are carried out for SPL and THD for each position and orientation (total of six combinations) for ten earphones, designated as E1 to E10.

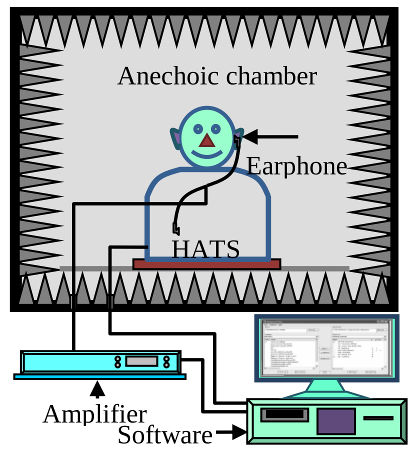

Figure 6: Measurement setup for an earbud earphone with B&K HATS.

The design and development of electroacoustic transducers like the loudspeakers, miniature loudspeakers, and earphones (like earbud and insert) are done extensively for getting consistent simulated performances. However, electroacoustic transducers are prone to manufacturing artifacts and no two loudspeakers may perform identically. There is a possibility of variation in the performance of the loudspeaker (SPL, THD, intermodulation distortion, rub & buzz, etc.) due to various factors. These factors might be defects, manufacturing variabilities, material discrepancies (compositional and structural), and service condition (working) histories (duration of sound production, mishandling, the amplitude of input signal, etc.). It is a general practice to observe the THD response of EE to identify the distortion and frequency response to see how the EE produces the sound of different frequencies. The high-fidelity sound reproduction is severely affected by the distortion in an output signal. In this study, the SPL and THD responses are measured for ten earphones (arranged in order of increasing price) available in the Taiwan market (May 2011) at three positions and two orientations. Minimum five readings are taken for each EE at a particular position and orientation for consistency in results. The details of earphones, dimensions and specifications are given in Table 1 and Table 2.

3 Results

The SPL and THD responses for earphones E1-E10 at position 1 and orientation 1 are given in Figure 7. The top plots indicate SPL responses and the bottom plots indicate corresponding THD responses. For better visibility and understanding, the left-side plots show the result of earphones E1 to E5, and the right-side plots show the result of earphones E6 to E10. The average reading of SPL and THD is given in all figures. Even though supplied with the same input signal, one can see that the SPL response of earphone E1 is lower than the remaining EEs; however, SPL responses of remain

Table 1: The dimensions of earbud earphones.

EE	Price range	Dimension (mm)		
		Dia-meter	Width/thickness	Openings/slits
E1	< US$ 3.0	16.5	W = 13.5	3 slits (opening) of diff. Length, Slit 3.3 x 0.5 (big)
E2		16.6	14	No hole in earphone cavity cover
E3	US$ 3.0~5.0	16.25	14.3	5 holes, d = 0.9
E4		16.5	15.0	2 slits, 1.5 x 0.3
E5	US$ 5.0~7.0	16.6	13.5	1 central oval hole a = 1.5, b = 1.0
E6		16.5	15.8	1 big slit, 4.5 x 0.8
E7	US$ 7.0~9.0	16.8	10.8	Annular slit 5.8 x 2.6 at the back along annular position
E8		16.5	13.8	1 central hole to earphone cavity cover
E9	US$ 9.0~11	15.7	14.6	1 central hole to earphone cavity cover
E10		16.2	13.0	Small annular slit, 3.5 x 0.5

D – Diameter of an earphone.
W – Width/thickness of an earphone.

Table 2: The specifications of earbud earphones.

EE	Specifications			
	Frequency Range (Hz)	Sensitivity (dB/mW) (SPL)	Impedance (Ω) at 1 kHz	Power handling capacity (mW)
E1	12~22000	108	16	50
E2	10~25000	100	16	40
E3	20~22000	105 ± 6 dB	16	5
E4	20~20000	104 ± 4 dB	16 ± 15 %	4 and 10
E5	14~22000	104 dB	16	50
E6	20~20000	105 ± 6 dB	16	5
E7	12~22000	106 dB	16	50
E8	20~20000	104	17	40
E9	16~20000	108	16	200
E10	12~22000	102 dB	16	50

ing EEs appear unique and nearly similar. The fundamental frequency of earphone E1 is higher than other EEs. Specifically, it is 630 Hz for E1 and 530 Hz for E10; however, the same is falling between 170-300 Hz for all other EEs. The highest and lowest SPL of the fundamental frequency is observed for E8 (129.9 dB) and E1 (99.9 dB), respectively, and for the remaining EEs, it lies between 109.9-122.0 dB. So, it concludes that the low-frequency response of earphones E2 to E10 may be carefully tuned by the design of the EE enclosure to get a high-fidelity bass response. All EEs show a spiky response after 1.7-3 kHz with a sufficient spectral component. The THD response of EEs illustrates that earphone E1 has high THD (~61.5% at 30 Hz). This response suggests the possibility of a significant nonlinear regular distortion, which may be due to the magnetic motor and suspension nonlinearities. Additionally, a peak (~8.2%) in THD at about 300 Hz is seen, which may be due to the rub & buzz or to some extent due to the manufacturing defect in the miniature loudspeaker of the earphone E1. Reduced SPL in the low-frequency region for earphone E1 can be correlated with an enhanced THD. Some small peaks ~0.1-1.6% THD are also observed at 1.6 kHz, 3.5 kHz, 4.75 kHz, and 7.1 kHz, which can be attributed to other irregular loudspeaker distortions. Based on the THD response, negligible high-frequency distortions are seen for an earphone E1. The SPL response of E5 shows enhanced spurious resonances than other EEs at 1.5 kHz, and THD response shows an observable peak (7.7%) at 85 Hz. Similarly, E6 and E8 THD response shows a noticable peak of 6.9% (560 Hz) and 18.4% (710 Hz), respectively, which may be due to manufacturing defects and rub & buzz. The acceptable frequency response should be flat over the required frequency range, and the THD will be 10% below 20 dB so that the main signal can mask it. The SPL responses for E6-E9 are approximately similar in magnitude and pattern. They show the fundamental frequency in the range of 200-300 Hz, and the spurious resonance starts after 2-3 kHz. However, there is an appreciable difference in their low-frequency (below 200 Hz) THDs. Due to the low THD over the complete frequency range, earphone E10 is found as best designed. The earphones E2 and E3 show negligible low-frequency THD and few insignificant mid to high-frequency peaks. The earphone E4 shows a climb of 12.3% THD at 112 Hz. Similarly, an earphone E5 shows a prominent ridge of 16.5% THD at 2.5 kHz. The earphone E8 shows the highest THD (~18.4%) at 710 Hz, earphone E9 shows a hill in THD (~14.3%) at 85 Hz, and earphone E6 shows a somewhat reduced THD (~10%) between 20-70 Hz. Another earphone E7 shows 16.1% THD in the range of 20-70 Hz.

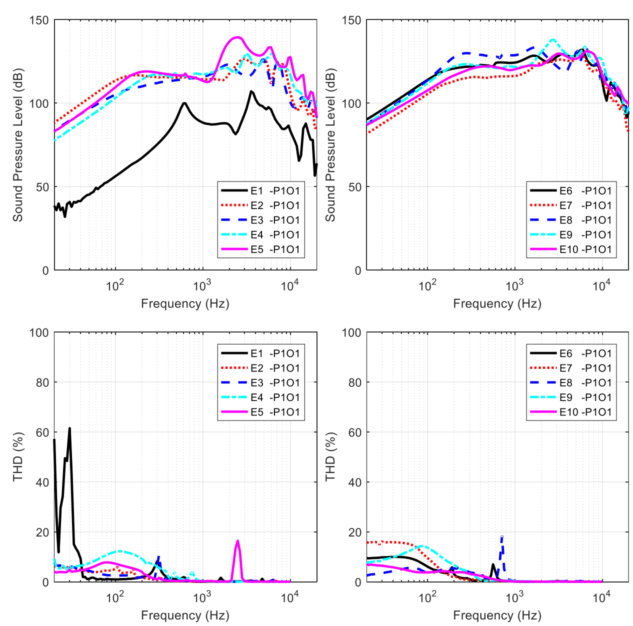

Figure 7: Frequency and THD response of Earphones 1-10 at position 1 and orientation 1.

For convenience, position 1 and orientation 1 is taken as reference (characteristic signature) for comparison of SPL and THD responses, which is widespread EE placement in the concha cavity. Figure 8 shows the SPL and THD responses of earphones E1-E10 at position 1 and orientation 2. Due to the change in orientation of EEs, there is a monotonous rise (except an initial dip at 22.4 Hz (Figure 7)) in the SPL of earphone E1 by 20-30 dB without affecting the characteristics of the curve. The changes in the SPL are due to a change in the position of the sound source about ERP, the increased volume of the cavity between EE surface and ERP, and circumferential support to the inclined earphone by the tragus. However, this may lead to sound leakage from the anterior notch and the tragal notch. This position change allows a smooth passage of the sound from EE to the tympanic membrane (eardrum) through an ear-canal. Most of the SPL responses (except E3) shows an increase from orientation 1 to orientation 2. For earphones E2 and E8, the SPL reduces by 7-12 dB and reaches up to 1.7 kHz. Similarly, for earphones E9 and E10, the SPL reduces by 5-10 dB up to 1.7 kHz. On the contrary, for an earphone E3, the SPL enhances by 5-10 dB up to 1.9 kHz. There is no significant variation in SPL of earphone E4 to E7. Above mentioned observation shows that the SPL depends on the orientation of EEs for the same position till the start of spurious resonances. For all earphones, the SPL response remains same after the start of spurious resonances For all earphones, the SPL response after the start of spurious resonances remains nearly the same and a spikier response after the second resonance analogous to Figure 7. The SPL responses of E6-E10 remains almost similar to Figure 7.

Based on the THD curve, it is found that the low-frequency THD peak is affected due to a change in the position of earphone E1, which results in an excessively large THD as a characteristic of E1. The THD response of E1 rises to 87.9% at 30 Hz with a small split peak of 47.7 dB at 25 Hz; however, mid and high-frequency THD almost remains the same. For remaining EEs, there are insignificant changes in the THD from orientation 1 to orientation 2, except for earphone E9, which shows a new peak of 5.4% THD at 2.8 kHz. It is found that EEs E1, E4, E6, E7, and E10 demonstrates noticeable low-frequency THDs at both the orientations, and is attributed to the higher sound leakage to the rear side of the earphones due to slits (openings that are bigger than sound holes) in the cavity cover. Based on the above hypothesis, one can conclude that the SPL responses are dependent on the orientations; however, it does not affect THD of EEs by a significant amount.

Figure 9 shows the SPL and THD responses of all EEs at position 2 and orientation 1. There is a monotonous rise in the SPL of earphone E1 without affecting the characteristics of the curve. More irregular SPL is found below 75 Hz. The low-frequency response of E1 is improved in magnitude on comparing with Figure 7. However, a significant change is found in the low-frequency THD trend and magnitude below 40 Hz. Thus, a strong correlation between SPL and THD is established with this behavior. The remaining THD curve remains the same. The responses of all other EEs remains similar but higher than that of E1. When compared with Figure7,

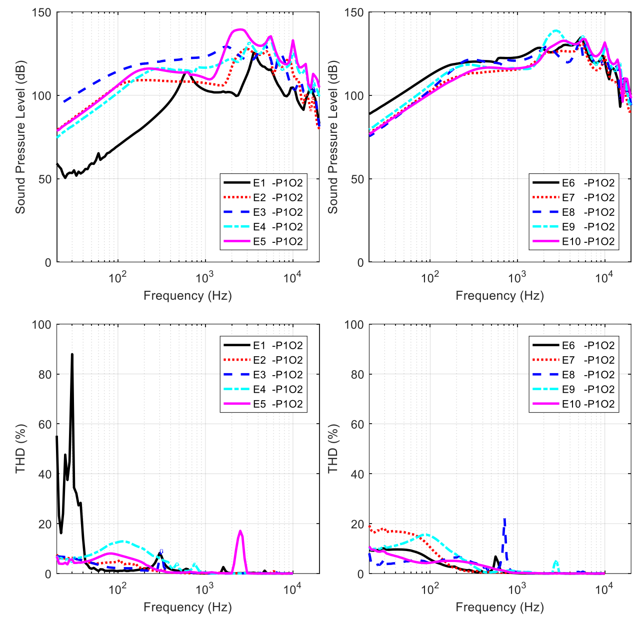

Figure 8: Frequency and THD response of Earphones 1-10 at position 1 and orientation 2.

for earphone E2, there is a reduction in the SPL by 15 dB till 1.7 kHz. For earphones E4 and E8, the decrease in SPL by 3-7 dB is found up to 1.9 kHz. Similarly, for earphones E5 and E6, reduction in SPL by 5-10 dB is observed until 1.9 kHz. On the contrary, there is no significant change in the SPL below the start of spurious resonances for earphones E3, E9, and E10. After the start of spurious resonances, the SPL response does not change by a significant amount. Some peaks are found in the THD responses viz. 10.4% at 315 Hz for E3, 3.9% at 475 Hz and 3.3% at 750 Hz for E3, 13.4% at 2.5 kHz for E5, 5.6% at 560 Hz for E6, and 19.9% at 710 Hz for E8. Except for E5 and E8, the rest of the THD peaks are insignificant. Also, some observable variations are found in the low-frequency THD responses for E7, which might be due to the biggest slit in the earphone cavity cover. The rest of earphones exhibits no change in their THD.

The SPL and THD responses of all earphones at position 2 and orientation 2 are given in Figure 10. The SPL response of earphone E1 mimics its SPL response observed in Figure 8. However, a significant change in the low-frequency THD can be found. A considerable variation in the magnitude of THD is observed as compared to Figure 9 and high THD is found below 40 Hz. For all the remaining EEs, the SPL responses below the start of spurious resonances reduce than their responses in Figure 7. Specifically, the SPL response of earphone E2 reduces by 6.1-8.3 dB in the 100 Hz-1.7 kHz. The SPL responses of E3 and E4 is lowered by an insignificant amount, similarly for E5 and E6 it lowers by 6-9 dB, and that of E7, E8, E9, and E10 drops by 0-2.4 dB, 8.8-12 dBSPL, 7-8.6 dB, and E10 3-7.1 dB, respectively. The THD responses of all EEs remains the same except for earphone E1. For earphone E1, besides the original peak, two distinct peaks are visible at 25 Hz and 37.5 Hz having 75.4% and 87.9% THD, respectively. The rest of the THD response of earphone E1 remains unaffected. Some observable variations in THD response are also found for E7. E9 also shows a new peak of 4.6% THD at 2.8 kHz. The rest of EEs do not show any deviation across the complete measurement range (Figure 7).

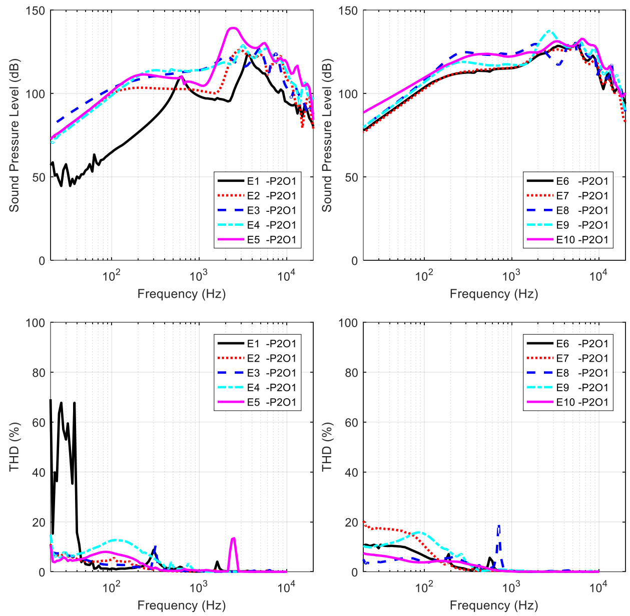

Figure 9: Frequency and THD response of Earphones 1-10 at position 2 and orientation 1.

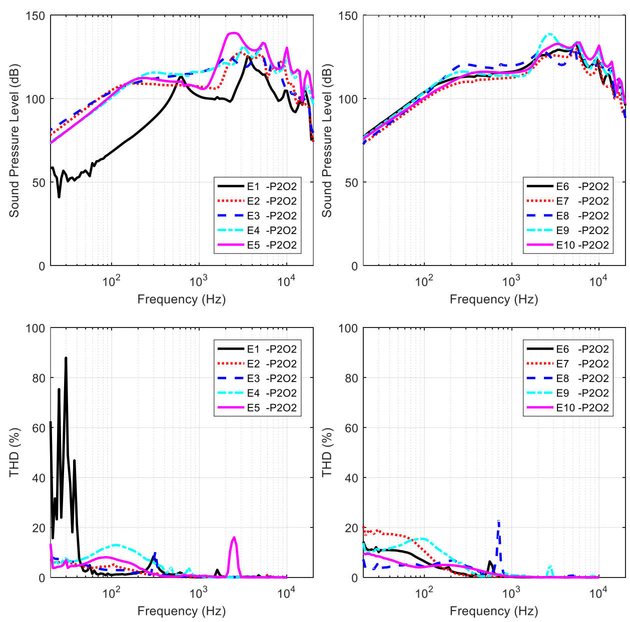

Figure 10: Frequency and THD response of Earphones 1-10 at position 2 and orientation 2.

The SPL and THD responses of all EEs at position 3 and orientation 1 are presented in Figure 11. The highest SPL response is seen for earphone E1. Also, its low frequency (20-60 Hz) irregular response became straight with a constant slope. It indicates that during this position of earphones, the sound source remains on axis with the opening of an ear-canal. This highest SPL response shows the corresponding lowest THD response as expected. Only one THD peak (47.3% 30 Hz) is observed, however the THD response over 40 Hz remains unaffected. For E2 to E10, after the start of spurious resonances, no variations are observed in the SPL responses ; however, below it, differences are found. The significant finding of these readings is that the highest SPL responses are seen for all earphones. The SPL response improves by 2-3 dBSPL for E2 and E8. Similarly, the SPL response improves by 7-10 dB for E3 and E10. Nearly 4-5 dBSPL improvement in the SPL response is also found for E5, E6, and E9. The most significant improvement in SPL response (8-15 dB) is observed for E4. Surprisingly, a decline by 2-5 dB in the SPL response is found for E7. The THD responses of all remaining earphones (E2-E10) remains unchanged when compared with Figure 7.

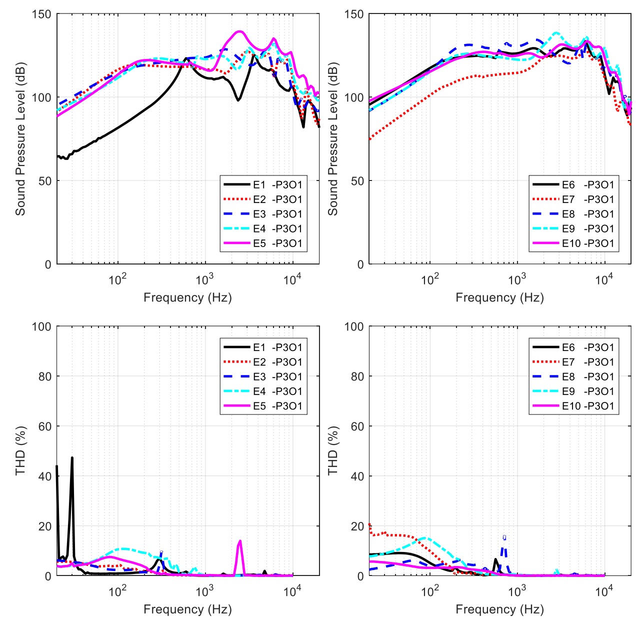

Figure 11: Frequency and THD response of Earphones 1-10 at position 3 and orientation 1.

The SPL and THD responses of all ten earphones at position 3 and orientation 2 are given in Figure 12. There is a monotonous rise in the SPL of E1, but with a slight reduction in the magnitude and with more low-frequency irregularities than given in Figure 11 without affecting the characteristics of the curve (Figure 7). The reduction in the SPL responses of E2, E8, and E9 by 2.4-11 dB is seen below the start of spurious resonances. The SPL responses of E3 and E10 exhibits insignificant variations in Figure 7. Additionally, the SPL responses of E4, E5, E6, and E7 shows a reduction by 2-3 dB, 5-6 dB, 3-5 dB, and 6-10 dB, respectively, with their responses (Figure 7). Significantly, the responses remain invariant after the start of spurious resonances for all EEs. The THD responses of all other EEs remain unchanged.

4 Discussion

Based on the relevant studies of human ear and variations in the anthropometric dimensions of ear it is expected that sound perception by different individuals from the same earphone shall be different. Some parameters like earphone shape, earphone size, earphone position in the concha, earphone orientation in the concha, earphone circumference and concha surface seal, earphone force on concha surface, etc., also contribute towards it. Extending further, this study proposes and establishes that the sound perception by the sameindividuals from the same earphone shall be different due to different orientations and positions of EE in the concha. The sound impression by the right and left ear of the same human being shall also be prone to differ due to dimensional variations. This study also infers that the prolonged usages of EE may also cause to change the orientation, position, force, earphone circumference and concha surface seal, etc. which may cause variation in the SPL generated across the tympanic membrane.

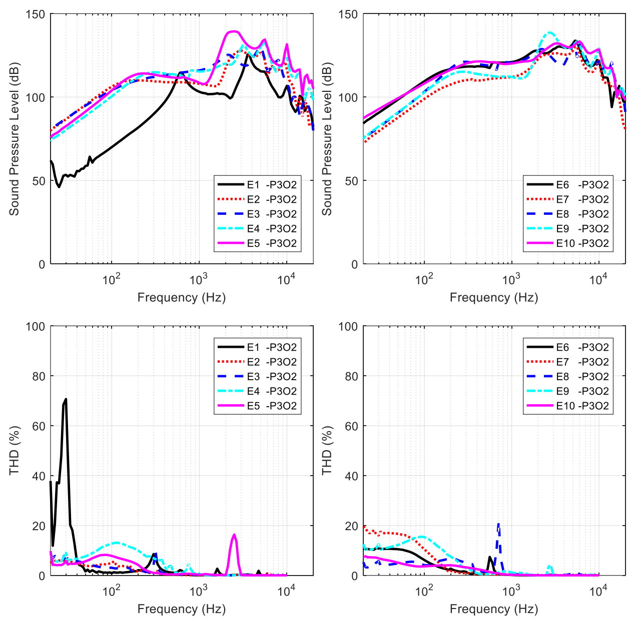

Figure 12: Frequency and THD response of Earphones 1-10 at position 3 and orientation 2.

The effect of the position of earphones in the concha cavity is explicitly seen in previous sections. In position 1, the earphone is placed firmly against the concha surface, and its wire lies along with the tragal notch. Hence, the front of the earphone remains closest to the concha and the ear-canal opening. Due to which the shape of the pinna external cavity gives reduced volume, along with small or no space for the sound leakage through space near the earphone wire. At this position, the miniature loudspeaker of the earphone might not remain close to the ERP, and the concha surface proximity due to reduced pinna external cavity volume shall provide resistance to the sound transmission through the air. Additionally, the volume across the tragal notch shall add in the pinna external cavity volume.

Similarly, at position 3, the earphone is placed firmly against the concha surface, and its wire lies along with the anterior notch. The anatomy of the tragal notch and anterior notch is different. Hence, a possibility that the front surface of the earphone remains firmly placed against the concha surface. However, at this position, the earphone casing firmly presses against the concha and possibly closes the volume across the tragal notch. Such anatomical dissimilarities result in variation in the earphone surface with an ear-canal opening and ERP. This results in the shape of a pinna external cavity that gives the least volume, along with small or no space for the sound leakage through the space near earphone wire and anterior notch.

At position 3, the earphone is placed so that its wire lies across anti tragus. The anatomy of anti tragus in reference to the anterior notch and tragal notch is different. The anti tragus is the projected portion, which results in the lifting of earphone wire from the concha surface. This position of earphone moves earphone front surface (diaphragm of a miniature loudspeaker) away from the ear-canal opening and ERP, but at the same time, there shall be an increase in the volume of the pinna external cavity.

The frequency responses of earphones were checked at 3 positions and 3 variations and found that the sound pressure variations are found without any deviation in the trend (shape) of the curve. Specifically, for E1, the lowest SPL is found at P1O1, and the highest SPL is found at P2O1 and the variation in the range of 20-25 dB across the complete measurement range. For E2, the lowest SPL is found at P2O1, and highest SPL is found at P3O1 and the variation in the range of 18-22 dB up to 1.07 kHz, for the remaining frequency range, all responses remain within 2-5 dB. E3 generates the lowest SPL at P2O1 and highest at P3O1 and the variation in the range of 10-15 dB up to 1.08 kHz, while responses remain within 2-5 dB for remaining frequency range. For E4, the response remains in 5-8 dB over the complete range at all positions and orientations except for P3O1, which is above all other responses by 10-20 dB up to 1.06 kHz. The frequency response of E5 indicates that at P2O1, the lowest SPL is observed, and at P3O1, the highest SPL is seen with the difference of 15-20 dB up to 1.02 kHz. However, the rest of the response remains in 3-5 dB. The E6 shows the lowest SPL at P2O1 and the highest SPL at P3O1 in the range of 15-20 dB up to 1.06 kHz, with the rest of the response in 3-5 dB range. The least variation in the response is observed for E7. The lowest SPL is found at P3O2 and the highest SPL at P1O1 with a range of 3-10 dB. The responses of E8, E9, and E10 are similar to E3.

It is estimated that the change of SPL by 3 dB is analogous to the change of sound intensity by a factor of 2. Similarly, 6 dB variation in SPL is equivalent to sound pressure variation by a factor of 2. An increase in the SPL by 10 dB corresponds to the sensation of doubling in volume (loudness) of sound. The perception of sound by a human ear is a very subjective process. A human ear as an organ can detect 1 dB change in the SPL. It cannot quantify sound in terms of the sound intensity and/or a sound pressure but can quantify it in terms of loudness. Thus, the quantitative analysis further reveals that a 10 dB change in SPL correspond to 10, 3.16, and 2 times changes in sound intensity, sound pressure, and perceived loudness. Based on the above hypothesis, it has been concluded that the variation in SPL is going to affect the perceived loudness of the sound. Additionally, on the other hand, based on an equal energy principle, a daily safe exposure time limit for a human changes/reduces by half for every

3 dB change/increase in the SPL, respectively. In particular, 80 dB sound exposure for 8 hours (say safe limit) is equivalent to 83 dB for 4 hours and 86 dB for 2 hours. It reduces further to 95 dB for 15 minutes. It is essential to recognize that the daily sound exposure limit of a human being is additive and commutative. Quantitatively, it implies that if one is exposed to 80 dB for 4 hours in a day, then for the safe exposure on the same day, he may be exposed to 83 dB for 2 hours or 86 dB for 1 hour only. Exposure beyond this limit may cause permanent hearing disorder(s).

Referring to anthropometry of the human ear [9, 10] for successful design, development, and market penetration of ear-related products, its correlation with the outcome of the current study of ten different EEs shall become inevitable. The measurement of SPL and THD of all earphones have been carried out by HATS-B & K Type 4128, which is the universally accepted manikin. The HATS is having a built-in ear and mouth simulators for genuine imitation of the acoustic properties of an average adult human head and torso. For this study, only the right and left pinnae of the silicone material are essential for investigations, since the earphones are in direct contact with the pinna at all positions and orientations during the measurements. The silicone pinnae resembles the human ear strictly in appearance and dimensions and are soft with hardness Shore-OO 35. The silicone rubber is a polydimethylsiloxane or silicone-based elastomer, which is widely used in medical, food, consumer industries, military, and aerospace. Moreover, both pinnae support insertion and sealing of earphones and are placed hanging in the concha. The placing of EEs in the pinna is in fixed relation to the ERP and EEP [1]. As depicted in Figures 2 and 3, all main dimensions of pinna become most significant after putting earphones in the concha cavity. Individually, L_a, L_{ab}, L_{ba}, and L_{ca} decides how effectively the crus tragus, tragus, and anti tragus encapsulates earphone cover during its use. So, for particular uses and a particular earphone, these dimensions establish definite relations with EEP and ERP. However, as reported in the literature [9, 20], the right ear is larger than the left one, so all the above-mentioned dimensions differ slightly. When the earphone is placed in the concha, it may lead to a slight difference in relation to EEP and ERP. As a result of these variations, the SPL and THD responses of the right and left ear shall vary. When counted all six possible combinations of positions and orientations of earphones in the concha cavity, the SPL and THD responses and hence, the perceived loudness (sensation of sound) shall be different. Considering the gender dependence of L_a, L_b, and L_c (male with larger ear dimensions than female), a particular earphone, when used by different gender, may result in variations in the SPL and THD responses, which ultimately leads to deviations in the perceived loudness of sound. It is also a prevalent fact that each human may have unique pinnae (size, shape, thickness anatomy, orientation, etc.), so the perceived sound by a particular earphone has to be strongly subject dependent.

Referring to the customer's habit of earphone use which may include, placement of earphone in concha, the volume of sound produced, type of sound produced, duration of use of earphone, environment in which earphone has been used (noisy or silent), time during which earphone is used, etc., one can find appreciable variations in the SPL and THD responses. The volume of sound produced by an earphone depends on the preference of the user for that sound, so the perceived loudness is as per the likings of the user, which in technical terms is analogous to the SPL response. The type of sound produced has strong dependence on the loudness of the sound (ultimately with the SPL response). Additionally, the user prefers to listen to favorite sound loudly than the other sound. In a silent environment, the user requires less loudness due to almost no interference of external sound from the sound produced by the earphone. However, in a noisy environment, a lot of inferencing sound is enclosed in the surrounding which results in masking of the sound. Hence, earphone user has to increase the loudness. A movement of the user's head can lead to the movement of earphones in the concha. Hence it induces the changes in L_a, L_{ab}, L_{ba}, and L_{ca}, and therefore causes the changed SPL response of the earphones. Referring to the user's health and condition of hearing system, may include, occupational sound exposure, hearing loss (as per audiogram), anatomy of an ear-canal, hairs in an ear-canal, body's natural ear wax in an ear-canal, moisture in an ear-canal, middle-ear and inner-ear anatomical differences, condition of auditory nerve (auditory pathways), condition of the brain stem which is responsible for the sound perception, etc. can affect the perceived loudness (SPL response). Mainly, an occupational sound exposure of user depends on the occupation of the user, duration of the occupational sound exposure, and the SPL to which the user is exposed during the occupational sound. An user's hearing loss affects the volume setting of earphones during use. Specifically, an user with no hearing loss would prefer low loudness than the user with mild hearing loss. However, an user with profound hearing loss needs appreciably high loudness. The anatomy of an ear-canal, hairs in an ear-canal, body's natural ear wax in an ear-canal, and moisture in an ear-canal also affects the perceived loudness of sound. The middle-ear and inner-ear anatomical differences, however small affects the perceived loudness. A condition of an auditory nerve (auditory pathways) and a condition of the brain stem, is responsible for sound perception and also accountable for the perceived loudness of the sound. Hence, all these factors are demands for certain loudness that is specific to the SPL responses. Discussing the technological supremacy of the earphone, includes cost of earphone, connectivity of earphone (wired or wireless), earphone with or without ear-clip, noise isolation (passive noise isolation) ability of earphone, anti-noise cancellation (active noise cancellation) facility of earphone, volume controllability (ear touch navigation) of earphone, etc., can also affect the SPL variations and the perceived loudness. High-cost earphones have better SPL and THD responses than other earphones. The wireless earphones are more stable in the concha cavity due to non interference of wire and the user's movement during earphone use. Earphones with ear-clip are better placed in the concha than the earphone without clip. Earphones with noise isolation and anti-noise cancellation are more superior than the earphone without it. The noise isolation earphone shall provide better stability to the earphone in the concha and also avoid the sound from the external environment to the concha cavity. The earphone with active anti-noise cancellation would provide the digital signal processing based methodology for recording background noise and subsequent inversion of it (creation of anti-noise). Finally, the addition of inverted noise with the input of earphone sound selectively filters out noise. Thus, all these factors also cause SPL and THD response variations.

5 Conclusion

Based on the observation and discussion, it can be concluded that EE can be placed anywhere in the concha of a human ear. As a result of routine practices, three positions and two orientations of earphone has been adjudged as the most significant. The SPL and THD responses for all earphones at position 1 and orientation 1 (which is the most common placement style of EE) can be declared as a benchmark. Based on the responses, it has been concluded that there has been variation in SPL and THD responses due to change in position and orientation. The responses at position 1 and orientation 1 are dominating and reflected in the SPL and THD responses of all earphones at all positions and orientations. It has been concluded that the SPL responses can be divided into three sections. Each section shows an unique trend and exclusive effect on the SPL response. The variation in responses finally affects the amount of sound reaching the eardrum for further processing. The proposition (10 dB changes in SPL correspond to 10, 3.16, and 2 times changes in sound intensity, sound pressure, and perceived loudness) leads to the interpretation that variation in the SPL definitely affects the perceived loudness of sound. Since the daily sound exposure limit for a human being is additive and commutative, variations in the SPL illustrated may have a significant effect on the daily sound exposure limit in hours. Finally, the impact on the perceived loudness (SPL response) has been found specific and user-dependent about the ear dimensions, user habits, and practices.

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VOWEL DISCRIMINATION ABILITIES IN QUEBEC FRENCH SCHOOL-AGED CHILDREN

Lucie Ménard * and Paméla Trudeau-Fisette †
Laboratoire de phonétique, Université du Québec à Montréal
CP 8888, succ. Centre-Ville, Montréal, H3C 3P8

Résumé

Bien que la perception auditive de la parole soit déjà bien développée dès la naissance, elle se raffine et se spécifie durant l'enfance et le début de l'adolescence. De nombreuses études ont documenté le développement perceptuel auditif précoce, mais très peu de données ont été obtenues sur les changements qui surviennent dans l'enfance. Cette étude a pour objectif d'étudier le développement de la discrimination de voyelles chez les enfants francophones du Québec d'âge scolaire. Des voyelles synthétisées qui s'opposent selon la dimension d'aperture et selon la dimension d'arrondissement ont été utilisées comme stimuli lors d'un test de discrimination. Quarante-neuf enfants âgés de 6 à 10 ans et douze adultes ont participé à la tâche. Les scores maximaux de discrimination des voyelles et les frontières catégorielles sont significativement différents entre 7 et 9 ans, ce qui suggère des changements dans le traitement auditif de la parole.

Mots clefs : perception de la parole, voyelles, développement de la parole

Abstract

Although auditory perception develops in infancy, it continues to mature until mid-adolescence. Many studies have documented early auditory perceptual development, yet very little is known about changes that occur in childhood. This study aimed to investigate the development of vowel discrimination in school-aged Quebec French-speaking children. Synthesized vowels contrasting along height and rounding were used as stimuli in a discrimination test given to 49 children aged 6 to 10 years old and twelve adults. Peak vowel discrimination scores and category boundaries shifted between 7 and 9 years of age, which suggests changes in speech processing.

Keywords: speech perception, vowels, speech development

1 Introduction

Speech acquisition is a complex process that entails the maturation of several biological systems. One of the challenges that newborns face is learning the phonemic categories of their native language. Those categories are formed through an important mechanism by which different instances of a sound are grouped into single perceived categories [1]. This mechanism, referred to as categorical perception, requires complementary perceptual skills, which include identification or labelling (the ability to link a sound to an appropriate phonemic label) and discrimination (the ability to distinguish between two sounds across categories) of sounds [2]. Several studies have shown that during the first months of life, infants undergo perceptual narrowing, which means that they gradually lose the ability to perceive contrasts between phonemic categories that do not belong to their native language (for instance: [3, 4]). Despite this achievement, a 1-year-old's ability to perceive phoneme categories in his or her native language is not yet adult-like. Indeed, a growing body of evidence suggests that infants and young children do not perform as well as adults in phonemic categorization tasks or discrimination tasks [5]. For instance, the slope of the identification function between pairs of phonemes (in an identification test) becomes steeper with age, reflecting better abilities to define phonemic categories in older children, compared to younger ones. This was found for the voice-onset time continuum in 2- to 14-year-old English- and French-speaking children [6], 2- to 6-year-old children [7], 6- to 12-year old children [8], and 5- to 10-year-old children [9]. This developmental trajectory may be related to the different cues used by children versus adults to identify phonemes. In a study of categorical perception of voice-onset time in French-speaking children and adolescents, Medina et al. (2010) [10] noted that the steepness of the identification function increased between 9 and 17 years of age, although no boundary shift was found.

Similarly, peak discrimination scores (in a discrimination test) also increase with age. For example, it was shown that low-frequency tone discrimination in 5-year-old children was poorer than in 7- and 9-year-old children, even after extensive training [11]. In a series of studies on consonant perception by children and adults, Nittrouer and col-

* menard.lucie@uqam.ca
† ptrudeaufisette@gmail.com

leagues [12-15] showed, through labelling and discrimination tasks, that 3- to 8-year-old children were better at discriminating dynamic cues than static cues, while the reverse was observed in adults. Boundary shifts between phonemes have also been shown to occur as a function of age [6, 16-18]. For example, Flege and Eefting (1986) [18] have reported that 9-year-old children did not display adult-like performance when perceiving the /t/ vs. /d/ contrast. Taken together, these results suggest that speech perception continues to evolve until early adolescence. The exact origin of these changes is still debated, and they probably involve cognitive, attentional, and language exposure factors, to name just a few.

According to Werner (2007) [19], the development of postnatal auditory processing involves three stages. The first stage lasts until 6 months old and concerns basic neural encoding processing, whereas the second stage extends from then until the start of the school years and allow infants and children to use more specific characteristics of speech sounds. The third stage begins when children start school and ends at age 8 or 9 (although some authors report some perceptual immaturity even in 12-year-olds). During the third stage, children fine-tune their auditory perception abilities. Werner's auditory-processing model is consistent with Burnham's (2002) [5] three-stage model of speech perception. Indeed, as soon as children learn grapheme-to-phoneme regularities of their language between the 1st grade and 5th grade (orthographic stage), the ability to perceive native contrast improves, whereas their ability to perceive nonnative contrasts deteriorates, with a marked dip at age 6 [20].

As can be seen by the increasing number of studies in this field, there is a growing interest in children's speech perception. However, most of the above-mentioned studies were conducted on consonant contrasts, and little is known about the effects of developmental changes on vowel-discrimination abilities in school-aged children. Vowel contrasts are known to be perceived in a more continuous manner than consonant contrasts. Nevertheless, developmental changes in vowel perception have been reported in some studies [13, 21-23]. For example, a study on the development of perceived French oral vowels investigated how 4- to 8-year-old children and adults labelled synthesized vowels [24] and showed that the children displayed different category boundaries and less steep identification slopes compared to the adults. To further investigate age-related differences in vowel discrimination abilities, the current study aimed to examine the ability of Quebec-French speaking 6- to 10-year-old children and adults to discriminate between two vowel pairs (with contrasting height and rounding).

2 Method

2.1 Participants

The study has been approved by the Université du Québec à Montréal's Institutional Review Board. Forty-nine children between 6 and 10 years of age were recruited: nine 6-year-olds (four males, five females), eleven 7-year-olds (five males, six females), nine 8-year-olds (four males, five females), eight 9-year-olds (four males, four females) and eight 10-year-olds (four males, four females). Twelve adults aged between 25 and 41 years-old (six males, six females) were also recruited. The participants were all native Quebec French speakers with no history of any language, speech or hearing disorder (self-report or as reported by parents and school teachers). In order to be included in the study, participants had to be native speakers of Quebec French and had to use Quebec French at home. The children attended public school in the greater Montreal area and were in kindergarten to grade 6. All participants were tested for pure-tone detection threshold using an adaptive method (Detection Threshold < 25 dB HL at 250, 500, 1000, 2000, 4000, and 8000 Hz).

2.2 Stimuli and procedure

Two sets of five-formant vowels ranging from /i/ to /e/ and from /e/ to /ø/ were synthesized using the variable linear articulatory model (VLAM, [25])[1]. Those two continua corresponded to two phonological features along which French oral vowels are produced: height (/i/ vs. /e/) and rounding (/e/ vs. /ø/). The formant values of the end-point stimuli for each of the two continua, listed in Table I, were those used in previous auditory perceptual studies with similar synthesized stimuli [26, 27]. The formant bandwidths for the five formants were calculated based on an analogue simulation [28]. For the /i/ vs. /e/ continuum, five stimuli were created between the end-points at equally stepped F1, F2, and F3 distances, as shown in Table 1 (for a total of seven stimuli). The rounding continuum, corresponding to the /e/–/ø/ dimension, was represented by eleven stimuli, equally stepped in F1, F2, F3, and F4 (see Table 1). A cascade formant synthesizer was excited by a glottal waveform generated by the Liljencrants-Fant source model. The resulting signal was digitized at 22 kHz and was 400 ms long. A fall-rise amplitude contour was applied to the signal. The F0 values were 110 Hz.

Table 1: Formant and bandwith values of endpoint stimuli used in the perceptual task.

Vowel	F1	F2	F3	F4	F5	B1	B2	B3	B4	B5
/i/	236	2062	3372	3550	4000	78	13	61	154	154
/e/	364	1922	2509	3550	4000	48	55	60	50	100
/ø/	364	1592	2069	3000	4000	88	40	19	19	19

Synthesized vowel stimuli from the two continua were presented to each participant in discrimination tasks. A classic AXB design was used. In this task, for a given continuum, A and B represent two stimuli that are one step apart on the synthesized continuum, and X is the same as

[1]The /e/ vs. /ɛ/ pair was also tested but was not analyzed because of its particular phonological status in Quebec French.

either A or B. After each AXB triad was played, the participant had to decide whether the second stimulus (X) was the same as the first stimulus (A) or the third stimulus (B). The interstimulus interval (interval between two triads) was 500 ms. Each triad was also presented in BXA form, where the order of the first and the third stimuli was reversed. Each triad was repeated three times, in each order (AXB and BXA), yielding a total of six repetitions for a given pair of stimuli (A and B). All stimuli were randomized across speakers and presented via headphones (AudioTechnica Profesionnal, ATH-M50x), at an intensity level of 65 dB (as measured by a GalaxyAudio sonometer). Adult participants indicated their response by clicking on a computer screen with a mouse. The children were asked to tell the experimenter if the first two or the last two sounds were identical, and the experimenter then clicked on the corresponding answer. A practice trial was conducted with all participants. The experiment started when they fully understood the task.

2.3 Data analyses

For each participant and vowel pair, percent correct discrimination scores were calculated. The highest percent correct discrimination score was extracted and considered as the peak discrimination score, for each participant and each stimulus continuum. Since the distribution of residuals, in percent, was right-skewed (non-normal), the data were log-transformed. The Shapiro-Wilk test suggested that the transformation was efficient and that the resulting log-based distributions were normal (p=0.445 for /i/ vs. /e/ and p=0.100 for /e/ vs. /ø/). The stimulus pair at which the peak discrimination score occurred was also extracted and corresponded to the category boundary. The effect of speaker age (6, 7, 8, 9, 10, or adult) on peak discrimination score and category boundary was assessed in a linear mixed effects model using the *lme4* [29] package implemented in R (R Core Team, 2012). Speaker age was the fixed factor. As random effects, intercepts for participants were entered. P-values were obtained by likelihood ratio tests of the full model with the effect in question compared with the model without the effect in question. For significant interactions, post-hoc tests were conducted using the *glht* function of the *multcomp* package (using the Bonferroni correction for multiple comparisons) [30].

3 Results

Log-transformed peak discrimination scores are presented for both vowel continua in Figure 1. Data were averaged within speaker groups. Regarding the height continuum (/i/ vs. /e/, blue lines), a significant effect of speaker group was found ($\chi^2(5)=9.12$; p<0.001). Post-hoc tests showed that peak discrimination scores did not significantly differ between the 6-year-old, 7-year-old, and 8-year-old groups of children. However, the peak discrimination scores were significantly lower in the 9-year-olds than in the younger or older groups (p<0.001). There was no significant difference in this outcome between the 10-year-old children and adults. A similar significant effect of speaker group on peak discrimination score was also found for the rounding continuum (/e/ vs. /ø/, red line) ($\chi^2(5)=11.96$; p<0.001), with 7-year-old and 8-year-old children having significantly lower peak discrimination scores than either 6-year-olds or older participants. Interestingly, for both vowel continua, peak discrimination scores did not significantly differ between 10-year-olds and adults.

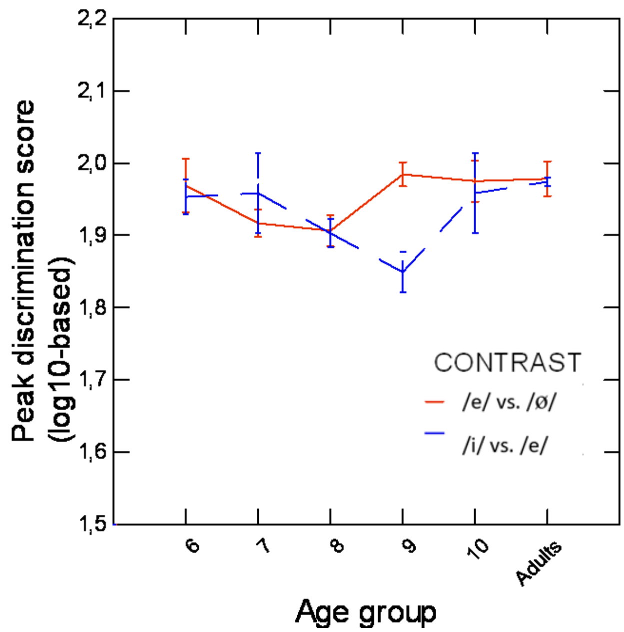

Figure 1: Average log-transformed peak discrimination score (log_{10}-based) for each age group. Data corresponding to the /e/ vs. /ø/ contrast are depicted in red, whereas data corresponding to the /i/ vs. /e/ contrast correspond to the blue lines. Error bars are standard errors.

Turning now to the category boundary along the height and rounding features, as can be observed in Figure 2, a shift in category boundary occurred for both contrasts between 7 and 10 years of age. Note that in Figure 2, y-axis values refer to stimulus pairs, along each continua. For the height dimension (/i/ vs. /e/, red line), in the 8-year-old children, there was a significant shift of category boundary compared to the younger and older groups ($\chi^2(5)=11.21$; p<0.001). The category boundary between /e/ and /ø/ was also significantly shifted in 9-year-olds compared with 10-year-olds ($\chi^2(5)=11.86$; p<0.001). As was the case for the values of peak discrimination score, no significant difference in category boundary along both vowel dimensions was found between the 10-year-olds and adults.

4 Discussion

The current study was designed to investigate the effect of age on the discrimination of two phonemic vowel contrasts in Quebec French: the contrast between /i/ and /e/ (height) and the contrast between /e/ and /ø/ (rounding). The results suggest that a perceptual reorganization occurs between ages 7 and 9. Indeed, concerning peak discrimination scores,

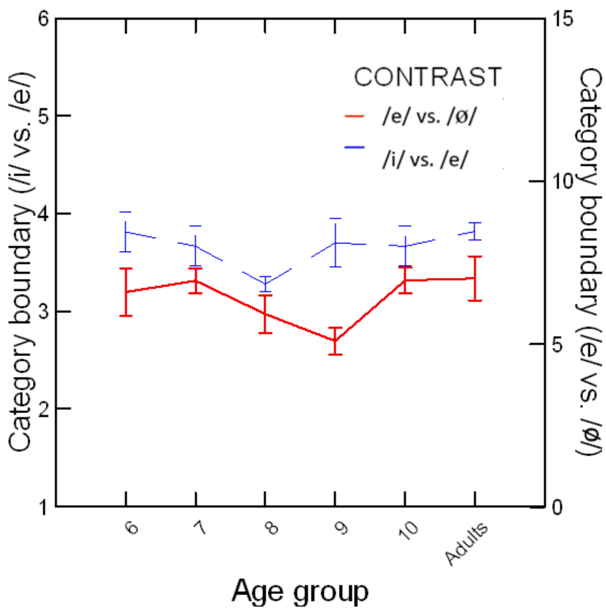

Figure 2: Average category boundary for each age group. Data corresponding to the /e/ vs. /ø/ contrast are depicted in red, whereas data corresponding to the /i/ vs. /e/ contrast correspond to the blue lines. Error bars are standard errors.

lowest values were found at 9 years of age for the height contrast, and at 7 and 8 years of age for the rounding contrast. The category boundary corresponding to these peak discrimination values also shifted between age 6 and 10 (at age 8 for height and age 9 for rounding). However, 10-year-olds and adults had similar values for peak discrimination scores and category boundary. It has to be noted, however, that for both peak discrimination score and category boundary, at 6-year-old, children had already reached values similar to the 10-year-old and the adult groups.

This pattern of results highlights the complex refinement of speech processing that occurs during the school years. Of note, the fact that discrimination performance along both vowel contrasts continued to mature until 10 years of age is consistent with previous work on consonant discrimination. Furthermore, as shown by Burnham's work [5, 20], as children enter the orthographic phase of native speech perception, their speech perception performance of nonnative pairs of sounds decreased between 2 and 6 years old and then increased in adulthood.

In the current study, several factors may explain this developmental trajectory, where specific higher-level speech processing abilities develop between 7 and 9 years of age. First, as children acquire lexical knowledge and refine their cognitive abilities, their perceptual phonemic targets become more flexible, so that they develop the ability to perceive speech in their native language that is produced with an unfamiliar accent [31]. A growing body of recent evidence also suggests that the ability to perceive speech in a language that is produced with an unfamiliar accent (for example, indexed by word recognition rates) develops over many years [32-35] and is not yet mature at 12 years of age ([31]). This new capacity likely influences perceptual boundaries between phonemes of the native language, momentarily weakening discrimination abilities. Furthermore, between age 7 and 9, phonological awareness develops substantially, along with reading skills. As suggested by Burnham (2002) [1] and Horlyck et al., (2012) [20], the development of reading skills imposes greater cognitive demand on children and affects their ability to discriminate between phonemes. It is also known that children do not weigh the visual cues provided by the speaker's face as much as adults do. For example, in a study of audiovisual perception in 5- to 14-year-old children and adolescents, Ross et al. (2011) [36] showed that the audiovisual gain in intelligibility steadily increased in this age group. Integrating this new sensory modality (auditory and visual) to a greater extent during childhood and adolescence might increase the cognitive load and influence auditory discrimination. Although these results cannot explain the change in vowel-pair discrimination scores in the current study, it is possible that this improved skill interacts with reading skills and other perceptual abilities that evolve before age 10. These hypotheses need to be explored in further studies involving, for instance, larger sample size. Such results could have impact on auditory assessment in typically-developing children. Indeed, changes in auditory vowel perception (at least for the two vowels contrast under study) characterize typical language development up to 10 years old.

It should be noted, however, that the stimuli tested in the current experiment consist in a limited set of synthesized vowels presented in isolation. Although the VLAM model has been shown to generate very realistic stimuli allowing fine control of acoustic parameters, further experiments with natural speech in a more realistic context are needed to confirm the aforementioned hypothesis on the development of speech perception. Another factor to further explore is the influence of language exposure on discrimination abilities. Despite the fact that children were native speakers of Quebec French and used Quebec French at home, they had little exposure to English at school (one hour per week). Their knowledge of English might slightly vary between speakers and, thus, could influence the results. Also, despite our efforts to include, in our participant sample, children who had Quebec French as their sole language at home, it is possible that children were also exposed to another language, besides French and English. Further studies should measure the degree of exposure to other languages to control for the effects of such variables on the discrimination scores.

5 Conclusion

The current paper aimed at investigating the development of auditory discrimination abilities for vowels in school-aged francophone children and adults. Results show that although children have attuned to their first language's category boundaries, their auditory discrimination skills still mature between 6 and 10 years old.

Acknowledgments

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The high scientific standards maintained by Canadian Acoustics in its papers owe much to the continuing dedication of the journal's reviewers, who give freely of their time and expertise. JCAA is pleased to pay tribute to this contribution by recognizing those who have participated in the review process. Thus, the Editorial Team of Canadian Acoustics acknowledge with particular gratitude the following reviewers who have reviewed papers during the last 12 months.

Les normes scientifiques élevées maintenues par la revue Acoustique canadienne doivent beaucoup au dévouement constant des réviseurs de la revue, qui donnent généreusement de leur temps et de leur expertise. JCAA est heureux de rendre hommage à cette contribution en reconnaissant ceux qui ont participé au processus d'examen. Ainsi, l'équipe de rédaction de l'Acoustique Canadienne reconnaît avec une gratitude particulière les réviseurs suivants qui ont examiné des articles au cours de la période des 12 derniers mois.

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2 FILL IN THE INPUT DATA
Indicate if you want to isolate a floor or a ceiling. Then introduce the weight per square meter and distance between hangers/ mounts.
Location
CEILING
FLOOR
Metric
METRIC
IMPERIAL
Load 6,6 lb/ft2
Distance between points
40 in
24 in
3 SELECT THE PERFORMANCE LEVEL
Introduce the natural frequency that you require. If you ignore this value you can select if your preference is high isolation or cost effectiveness. You can also select if the elastic material is rubber, Sylomer or spring.
Freq 9 Hz
I know the natural frequency
Material
RUBBER
SYLOMER
SPRING
CONTINUE
4 SELECT THE INSTALLATION TYPE
In case that you want to isolate a ceiling, you must indicate if the hanger has to be anchored to the slab, to the metallic beam or between rods. This will provide you a range of selected hangers and mounts that will fulfill your requirement.
Finally select the hanger that suits best.
Straight to profile
Straight to slab
Between threaded rods
SEARCH RESULTS
AKUSTIK GB + SYLOMER®
Number of items in this product range: 2
AKUSTIK LATERAL + SYLOMER®
Number of items in this product range: 2
5 OBTAIN RESULTS
This will lead you to a page where you will be able to check the isolation level. On this page you will be able to receive the complete vibration isolation level, data sheet, installation video or even request a quotation/offer.
AKUSTIK LATERAL + SYLOMER 30 TYPE B
REFERENCE 23510
DEFL. 0.15 in
LOAD 66.52%
NAT. FREQ. 8.73 Hz
Name: AKUSTIK LATERAL + SYLOMER® - Akustik Lateral + Sylomer 30 Type B
Date: 5/24/2019 12:45 PM
Reference: 23510
Load (lb.): 43.99
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
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300 Hz / 99.92 % / 61.44 dB
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2019 CAA MEMBERS SURVEY AND ACTION PLANS

Jérémie Voix [†1] Alberto Behar [‡2] Umberto Berardi [‡2]
[1]Université du Québec (ÉTS) | 1100 Notre-Dame Ouest | Montréal (Qc) Canada | H3C 1K3
[2]Ryerson University, 105 Bond Street,Toronto, ON, M5B 2K3

Résumé

Conscient du rôle très important joué par ses membres et afin de mieux les servir, le conseil d'administration de l'ACA a décidé en 2019 d'envoyer une enquête à tous ses membres actuels et passés afin de mieux comprendre comment ils se portent et comment elle pourrait améliorer le service à ses membres. Cet article présente les questions envoyées, les réponses reçues et détaille, pour chacune d'entre elles, un plan d'action proposé.

Mots clefs: ACA, membres, abonnements, pérénité, affaires internes

Abstract

Aware of the very important role played by its members and in order to better serve them, CAA Board of Directors decided in 2019 to send a survey to all its current and past members to better understand how it is doing and how it could improve the service to its members. This article presents the questions sent out, the answers received and details for each relevant one a proposed plan of action.

Keywords: CAA, members, membership, sustainability, internal business

1 Introduction

The Canadian Acoustical Association (CAA) is the professional, interdisciplinary organization, born in 1973, that:

1. fosters communication among people working in all areas of Acoustics in Canada;
2. promotes the growth and practical application of knowledge in Acoustics;
3. encourages education, research, protection of the environment, and employment in Acoustics;
4. is an umbrella organization through which general issues in education, employment and research can be addressed at a national and multidisciplinary level.

Aware of the very important role played by its members and in order to better serve them, CAA Board of Directors decided after its spring 2019 meeting to send a survey to all its current and past members to better understand how it is doing and how it could improve the service to its members.

Such decision came following many conversations held during Acoustics Week in Canada 2018 (AWC18) in Victoria (BC), either during the Board of Director itself, the General Assembly or through informal conversations, where it was felt by the CAA Board of Directors that the members had to be inquired about their needs and that an online questionnaire survey could be a worthy first exercise, in order to seek CAA members at large, while focusing on sustaining subscribers and other commercial entities (consultants, sponsors and exhibitors, etc.)

2 The Survey

2.1 Preparation and distribution of the survey

An online questionnaire was drafted early June 2019 by CAA President and circulated a couple directors, who volunteered to be part of a so-called “Membership Task Force”. A link to the final version of the online questionnaire was sent to CAA general mailing list. This mailing list regroups all 632 current and past individual members, 108 current and past institutional members of CAA as well as all 1044 authors, editors, reviewers and 5,364 readers of Canadian Acoustics journal collected over the last 45 years of existence of CAA, summing up to 5,517 unique email addresses (the same person can belong to more than one category, for example, a reader of the journal, can also be an author and can also be a member of CAA).

2.2 Email blast

The content of the email sent out on June 6, 2019, is presented in Figure 1.

[Message en français ci-dessous]

Dear CAA Members and Colleagues,

Aware of the very important role played by its members and in order to better serve them, CAA Board of Directors recently decided to send a survey to all its current and past members to better understand how it is doing and how its could improve the service to its members. This survey will take only 10 minutes of your time :

https://forms.gle/7vq5GtZ7TXJmLmAv9

Thank you for sharing your comments and ideas. This can make a HUGE difference to your beloved association! 🙂

Acoustically yours,

Jeremie
--
Jérémie Voix
President
Canadian Acoustical Association

Chers membres de l'ACA et collègues,

Conscient du rôle très important joué par ses membres et afin de mieux les servir, le conseil d'administration de la CAA a récemment décidé d'envoyer un sondage à tous ses membres, anciens et actuels, pour mieux comprendre comment il va et comment il pourrait améliorer le service. ses membres.

Ce sondage ne prendra que 10 minutes de votre temps :

https://translate.google.com/translate?hl=&sl=auto&tl=fr&u=https%3A%2F%2Fforms.gle%2F7vq5GtZ7TXJmLmAv9

Un énorme merci pour vos commentaires.

Acoustiquement vôtre,

Jérémie Voix

P.S.: L'ACA est toujours à la recherche de volontaires pour la traduction et l'adaptation de nombreux messages. N'hésitez pas à nous contacter pour plus d'information.

Figure 1. Content of the email sent out to members.

2.3 Description of the survey questionnaire

The respondents were offered to fill in an online questionnaire, reproduced in Figure 2, consisting of 8 questions among which 5 were open-ended. The total number of qualifying respondents who participated in the survey is 46. This number appears at first sight to be very low compared to all the emails sent out, but decent when compared to the actual number of current individual (170) and institutional members (41), towards which the questionnaire was really aimed at.

3 The Results

The responses to the online questionnaire were retrieved 2 weeks after the initial posting and compiled. The resulting outcome is presented in the following sections.

Responses from the Survey

As seen in Fig.3 for the **membership status** (Question 1) the majority of respondents (70%) are registered members.

As seen in Fig. 4, almost all respondents (89%) turned out to be individual members, confirming the assumption that only members and past members of CAA would take time to fill such questionnaire (as opposed to authors and readers who have also been contacted).

CANADIAN ACOUSTICAL ASSOCIATION
ASSOCIATION CANADIENNE D'ACOUSTIQUE

1. **Membership Status** *

We are sending this survey to all CAA past and current members and you appear to be one of them. As this survey is anonymous, could you kindly specify your current membership status?
Mark only one oval.

- ⬭ currently a registered member
- ⬭ no longer a registered member
- ⬭ don't know. HINT: you can check your status online by logging in at https://jcaa.caa-aca.ca/index.php/jcaa/user/subscriptions
- ⬭ not interested in CAA anymore. HINT: we can definitely remove you from our member database if you write to us directly at secretary@caa-aca.ca

2. **Membership Type** *

What is (or was) your CAA membership type?
Tick all that apply.

- ☐ individual member
- ☐ sustaining member (you are the point of contact)
- ☐ institutional subscriber
- ☐ don't know. HINT: you can check your status online by logging in at https://jcaa.caa-aca.ca/index.php/jcaa/user/subscriptions

3. **The Good** *

CAA's mission is listed at the top of this survey. Tell us what CAA does (or did) right for you with regards to its mission.

4. **The Bad** *

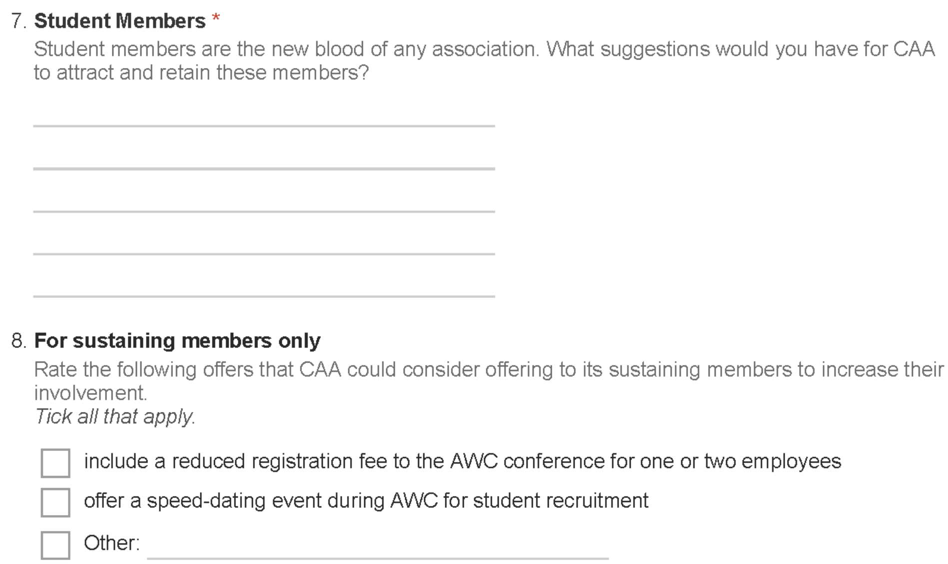
CAA's mission is listed at the top of this survey. Tell us what CAA could do (or could have done) better for you with regards to its mission.

5. **The Ugly** *

We are all volunteers and the Directors choose to devote a lot of their time to sustain CAA's mission. We are all ears for your constructive comments and advice

6. **Sustaining Subscribers** *

Sustaining members are companies or institutions who pay currently 375$/year to receive free access to Canadian Acoustics, enabling wide distribution of its journal at a reasonable cost and assisting with other initiatives. A list of all Sustaining Subscribers is published on the back cover of each issue of Canadian Acoustics and on the Association's website. While this institutional subscription is linked to an individual contact person, that individual or the subscribing organization do NOT receive the rights of Members (such as voting privileges). What suggestions would you have for CAA to attract and retain these members?



7. **Student Members** *
Student members are the new blood of any association. What suggestions would you have for CAA to attract and retain these members?

8. **For sustaining members only**
Rate the following offers that CAA could consider offering to its sustaining members to increase their involvement.
Tick all that apply.

- [ ] include a reduced registration fee to the AWC conference for one or two employees
- [ ] offer a speed-dating event during AWC for student recruitment
- [ ] Other: ____________

Figure 2. Copy of the online questionnaire forms

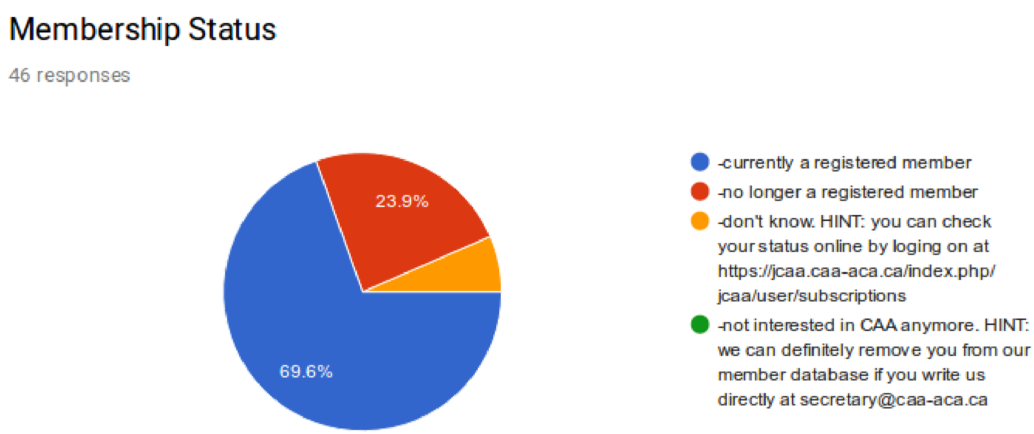


Figure 3. Membership status (46 responses)

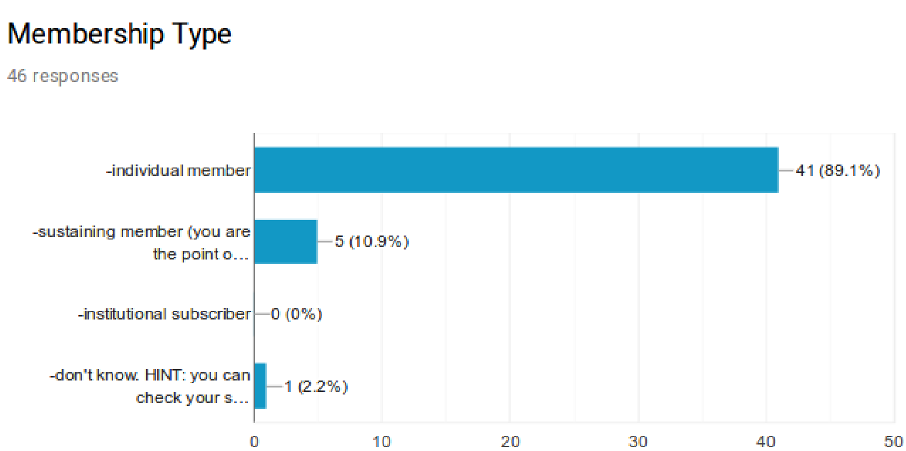


Figure 4. Membership type

Table 1. Responses to a question about good sides of CAA work and mission. Denoted by letter "G".

G1	Allow me present two papers
G2	You are still running after 40+ years.
G3	Promoting the growth and practical application of knowledge in acoustics
G4	Sending the survey is good. Hope to do survey every year.
G5	clear statement
G6	I think it does a great job.
G7	Nothing
G8	Provides a good forum for networking with professionals in our industry.
G9	organize the CAA-ACA congress along Canada, supports initiatives for education and research
G10	CAA conference has provided an opportunity for communication, but (see below)...
G11	All of it
G12	It's good to have a national association and the conferences are generally useful. I don't know if it's sanctioned or independent, but John Swallow's Toronto CAA talks have been fantastic.
G13	CAA's AWC is a good way to stay in touch with local practitioners.
G14	CAA has done a great job promoting acoustics in general within Canadian educational institutions and some industries. It also played a significant role in educating the public about the importance of acoustics.
G15	It is great to have friendly journals and conferences.
G16	ok
G17	I believe the CAA is doing a fair job in fulfilling its mission stated above.
G18	N/A
G19	Papers in architectural acoustics were helpful for my acoustical consultancy.
G20	The fact that papers published in Canadian Acoustics will become open access after 12 months is a very good thing.
G21	#1, #2. I really enjoy the wide variety of content presented.
G22	kept me up to date with research in Canada
G23	Access to all kinds of resources and small acoustic community in Canada
G24	Friendly atmosphere where discussion is encouraged. Feels like a real community, certainly among the older generations. Also seeking the opinions of the membership is most welcome.
G25	very collegial, great for students
G26	I am very much satisfied with the services provided by CAA.
G27	Promotes growth and application of acoustics
G28	Having open access to the journals. Love the new website design with easy to find information.
G29	maintains activity in acoustics
G30	Conferences
G31	I feel like number 1 was most impactful in my experience.
G32	Allows interaction among people with similar backgrounds
G33	Les nombreuses bourses à disposition des étudiants. Le meeting annuel Le support pour les étudiants (défraiement des frais de voyage)
G34	Keeps the acoustical community connected.
G35	Strong support of students and activism for acoustics research in Canada
G36	Dedicated volunteers to promote the mission
G37	Good forum for publication of evolving research in acoustics, in the form of the Journal and the conference.
G38	The journal does a good job of sharing information and conference papers with people involved in the field country-wide.
G39	Informs the top rated content in the field of acoustics
G40	fosters communication among people working in all areas of acoustics in Canada
G41	promotion of communication between acousticians, through its journal and through its annual meeting
G42	Though we're rather new to our membership, CAA was apparent when searchable online, presents a list of operations and supporter that represent a function of the acoustic practitioners in Canada, is open to new membership, and is drawing together very useful material for us to reference as a practitioner. Although we haven't yet connected directly with anyone other than the secretary of the CAA, we're excited to try to draw upon connections with fellow operators in the industry, and hope to find openness to discussion and coordination.
G43	Publishes a Journal and makes the articles from back issues available free of charge Organizes a Canada wide (international actually) annual conference and provides educational opportunities, supports

	students through awards. Has provided a means by which noise control/acoustical suppliers can network freely with consultants and end users.
G44	It does foster communication among people working in all areas of acoustics in Canada through its annual conference.
G45	I am generally happy with how the CAA runs
G46	Point #1 in the mission, because we are a small organization we are very interdisciplinary and I think that helps us all.

Table 2. Responses to a question about the bad sides of CAA work and mission. Denoted by letter "B".

B1	Help connect new members to employers
B2	A lot of consultants and academics in acoustics are not member
B3	I didn't hear much about education in acoustics.
B4	Lack of job and networking opportunities in Vancouver area
B5	promoting young researchers
B6	CAA could give one of its members (Rich Peppin) $1,000 USD as a token just for living in Rockville, MD
B7	improve journal indexes and specify what is impact factor, publication time, so on. Follow the same society of America
B8	Nothing bad to say
B9	Communication between people working in all areas of acoustics in Canada could be possibly improved
B10	Was disappointed that CAA conference rejected a paper I had offered for conference in 2017 for no defined reason other than a cryptic note that conclusions of my research differed from Health Canada point of view about wind turbines. The rejection was based only on the brief abstract which of course was not the full paper. Neither did the rejection offer any way to make the presentation acceptable. As a result the research was instead published in a peer reviewed international journal, which probably gave it even greater exposure. As a result I have not offered other work to CAA. Disappointed.
B11	Not enough of any of them
B12	There's very limited programs for acoustics in Canada, and almost all at the graduate level. It would be great to see more being done with the schools to get undergraduate programs or courses. There also, to me, appears to be a bit of a divide between the "consultants" and the "academics". It would be nice to integrate the two more. I don't think I've seen a student prize winner or, for that matter, student goes into one of the consulting firms.
B13	Not enough of the country's environmental noise practitioners embrace CAA. It would be great to have a further reach to be able to more completely unite practitioners across the country.
B14	CAA should focus on more practical application in all areas of noise control. I believe it has been more focused on theoretical, educational and academic papers/topics rather than day to day industry needs. This may be due to the lack of interest most noise control manufacturers and practitioners showed in providing papers and literature to the association but the interest needs to be revamped and refreshed. We need to motivate and engage more people from all industries in promoting their ideas, solutions and products for acoustics.
B15	It could try to reach the public or administrative authorities about noise.
B16	no
B17	I don't have the answers, but I doubt many people outside of CAA members even know about us. Most would probably think CAA stands for Canadian Automobile Association or something other than Canadian Acoustical Association. I recognize that obtaining that recognition takes a lot of effort and advertising money, which we don't have...
B18	Don't really get much out of it. But I don't contribute anything either. I prefer to put my efforts into ASA.
B19	For me more papers in building acoustics would be helpful.
B20	.
B21	#3 - did not really know this was a thing. Perhaps include an article on this subject in every issue?
B22	not really anything
B23	Better communications within the community.
B24	Could really use more local chapters to drive CAA membership up. Having local meetings that provide useful information to consultants about developments in their field at a local and national level and maybe organised social events would likely increase the possibility of joining CAA, which frankly most of my fellow consultants do not know exists or see any benefit to being a member of. For example, the IOA in the UK had Scottish branch meetings every 3 or 6 months, where feedback was sought on the development of new standards, guides, best practices, product innovations, etc. A social event in a restaurant / bar would typically follow (attendees pay). Toronto at least

	seems to be now doing the meeting part, but CAA should be driving its members to participate in discussions by key personnel organizing discussions that are relevant to them and their work. In my company we have maybe 15-20 acoustical consultants, yet I think maybe 1 other person here is a member of CAA. In my last consultancy in the UK, we had 12 consultants, all of whom were IOA members. We are a private company, and realistically will not be sending junior (even most senior) staff to conferences unless the conference was on our doorstep and at most $100-150 per attendee for a per-day attendance. But all of our staff could attend a local chapter meeting when reasonably priced and informative/worthwhile. Given the long distances and cost, most consultancies will not send staff outside their province... there is no reason conferences cannot be webcast either live or after the event nowadays to increase participation and knowledge transfer... those that want the in-person interaction will still attend as before, whilst having the ability for a company to purchase webcasts of individually selectable presentations would allow us to educate staff on particular topics, as well as giving CAA feedback on what are the most useful presentations. A discount for conference exhibition/attendance for sustaining members is a good idea. Finally, there is probably a good and historic reason why the conference is in October... but September would be a lot more pleasant in many parts of the country!
B25	more leadership on multi-disciplinary research and knowledge translation
B26	I hope CAA will give a better discount for continuing members.
B27	better contact with researchers in speech communication ..activity level is low in this area
B28	Not having an outspoken active social media account (at least to my knowledge) that is promoting articles and news about acoustics frequently. Should be finding and following all (public) members and worldwide acoustics practitioners and retweeting good information. Spreading acoustics awareness including latest innovations and news as well as health concerns etc. Website updates also not frequent enough. Maybe have CAA meeting minutes and decisions published on the website so we can see what's going on without having to wait for the published issue to come out several months later.
B29	does not have the ability to address general issues like public policy
B30	Publications in journal and conference proceedings do not get as much international exposure as other organizations and publications.
B31	employement opportunities could be more diverse
B32	You are doing alright no need to change
B33	Le site web n'est pas toujours très clair pour les auteurs. Plusieurs fois, ceux-ci éprouvent des difficultés quand ils veulent uploader les révisions de leurs articles, surtout après le copyediting (le bouton n'est pas assez visible). Il ne devrait pas être très compliqué d'améliorer ce point-ci avec l'aide du webmaster. Il y a des différences mineures entre le gabarit LaTeX et le Word. Celles-ci pourraient être fixées. Le gabarit Word a plusieurs erreurs (des espaces surnuméraires par exemple). La mise en page de plusieurs choses ne’est pas précisée dans les gabarits actuels dont par exemple : les équations, les listes avec puces et/ou numéro, etc... Une mise à jour de ces documents serait la bienvenue.
B34	wish it was a little more focused on the acoustical consultant community and had more consultant members.
B35	In part, my lack of involvement is due to just making choices for conferences. I only wanted a few meetings a year and I wanted more specialized, bigger impact meetings. I viewed the CAA meeting as one that didn't have enough people in my specific area.
B36	As with most organizations, encouraging younger people to fully take part and especially to volunteer to be an executive isn't easy. The same group of people ends up doing the majority of the work to sustain the organization.
B37	Could be more than just an academic association. E.g., the conferences held by (former) Alberta Energy and Utilities Board every 3 years were excellent at this, while they lasted. They were able to cater equally to academics, consultants, suppliers and industry. My experience is that, in an effort to raise the profile of the Journal (by mimicking the refereeing process of more established publications, but without the necessary knowledge base amongst the reviewers), the CAA has turned the Journal into a much more esoteric forum, and has alienated consultants, suppliers and industry from successfully submitting articles.
B38	Communications about the conferences is poor - need more notifications/emails before the abstract submission due date
B39	The frequency of newsletter, issue information Is quantitatively low, this also means the content is highly focused instead of varied applications
B40	promotes the growth and practical application of knowledge in acoustics
B41	no bad
B42	Other than the academic journal, and again without having been a member long yet, we've not yet seen any overt connection building or events that might foster direct communication with fellow practitioners.

B43	I come from the Consulting world, and frankly, it has been difficult at times to have papers published in the Journal. It is very academic in format and papers must be peer reviewed. I am not suggesting that is a bad thing .....but most consultants are more motivated by sharing information on a less formal more time efficient basis. The two page format used for the Acoustics Week in Canada issue is good. It is quite a straightforward and time efficient way of presenting Case Studies or provocative articles, but has some shortcomings. 1) Such papers are only accepted if the author has registered for the conference, ostensibly to promote conference attendance. That may be why so many such papers are multiply co-authored as consultants have to be quite selective with their time. Quite literally, time is money, and anything perceived as a waste of time or a poor return on investment is not considered worthwhile. 2) Two page format papers are not accepted in other Journal Editions as far as I know. 3) An important function of the Journal for a Consultant is to keep up to date with the fast changing advances in technology, and if suppliers do not advertise in the Journal, consultants may not find much value in it. 4) Similar comments apply to the yearly conference. If exhibitors shy away that is also a disincentive to membership and conference attendance for Consultants. It is a bit of a Catch 22. Exhibitors don't see value because they perceive that consultants don't see value because they perceive that exhibitors don't see value. It is kind of a vicious circle that we need to think hard about breaking out of. Sure it is nice for Consultants to rub elbows with academics and throw around ideas and think about collaborative ventures. Personally, I enjoy doing that, but little of value tends to come from that in a business sense. More value tends to come to consultants by rubbing elbows with suppliers/exhibitors.
B44	I'm not sure the CAA has encouraged education and research in acoustics as education options in Canada seem to be disappearing. I'm not sure the CAA has promoted the practical application of knowledge in acoustics because the conference seems to be very academia focussed and acoustical consultants are largely not interested in attending.
B45	Nothing.
B46	Point #4 in the mission, I'm not sure this comes across as strongly from the POV of casual (i.e., not very involved) members

Table 3. Responses to question about worst sides of CAA work and mission. Denoted by letter "U".

U1	**The board is doing well**
U2	Be recognized as a professional organization (tax credits)
U3	None
U4	Use of social media such as facebook and linkedin could help connect members
U5	don't know
U6	I've been pushing this for years but it doesnt seem to take hold (maybe because no one like sit but me: a) Have a category of membership called FELLOW. Most professional societies do and it gives some prestige to those that get nominated. b) Have a membership category called LIFE MEMBER. If say, regular membership is 100.00/year, LIFETIME could be, 1,000.00 for those under 50 and 750.00 for those over. The actual amounts would have to be figured out more carefully but this class would do two things: 1) give CAA guaranteed money, 2) a relief from paying dues for those that took advantage of the system. (ASME, ASTM, ASHRAE, are among societies that have this.)
U7	American Society of Acoustic is popular, why CAA is not? It is because of its poor journal and seminars. You should follow their method to improve this society.
U8	Nothing really ugly to say
U9	developing resources (web, toolkit) for educational purposes that could be used across Canada in school, colleges, science fairs
U10	None, other than to be open to different points of view when supported by facts.
U11	Increase membership. Give more to members.
U12	It's not the CAA's fault but travel within Canada is very expensive. Americans can fly coast to coast for quite little compared to Canadians. This means that conferences in some cities, along with hotel and registration fees, can be very, very expensive. Currently, other than a journal and the conference, I don't know what the CAA does. I don't see much broad action promoting the industry.
U13	It would be great to see more involvement with CAA and schools - not just things like encouraging student papers, but connecting practitioners to interested secondary or postsecondary schools to help promote our craft. Organizations like the PEO run various programs to encourage this sort of interaction.

U14	As mentioned above, we need to provide interest and motivation for noise control companies to join and support the association. This can only be done by offering them real and tangible benefits (it could be as simple as a satisfaction they get from sharing a success story in resolving an acoustical problem or a new product). Currently there are over 100 companies involved with acoustical products, noise and vibration control, and related industries in Canada. Less than a handful are involved with the association.
U15	Sustaining members back page was almost full a few years ago, now it is 1/3.
U16	ok
U17	I appreciate the efforts all the volunteers and Directors put in. However, I prefer surveys that offer me choices for answers, rather than open-ended questions. I almost decided not to bother doing the survey once I saw the format.
U18	N/A
U19	Keep up the good work.
U20	Would it be possible to produce a brochure or small poster about the CAA? These could be posted by members attending confererences and may be a way to increase the numbers and diversity of the membership.
U21	I like the articles that are presented, but if the mission of CAA is to "encourage education, research, protection of the environment, and employment in acoustics" and be "an umbrella organization through which general issues in education, employment and research can be addressed at a national and multidisciplinary level", I don't see any of that effort shown in the Journal (basically the only form of communication I receive from CAA). Keep the journal-style articles, but also include informative articles about how the CAA is progressing along those fronts.
U22	na
U23	Cannot think of any. If needed, I am willing to volunteer as well.
U24	The last AWC in Victoria cost $870 registration fee, compared to $495 for Guelph... I get that this was due to the twinning with ASA, but it is hard to argue that even a twinned conference was worth this (ASA alone certainly isn't) and I struggle to justify to my company continued attendance if the registration fees go above $500.
U25	na
U26	None
U27	nothing comes to mind
U28	See answers to "the bad".
U29	-
U30	I have no idea how directors are selected. It's a complete mystery. I don't vote.
U31	I think it's a great volunteer organization
U32	See above!
U33	Le manque d'implication de la communauté dans certaines disciplines est parfois une contrainte lourde notamment lorsqu'il devient relativement difficile de trouver des reviewers pour les articles. Ce problème (récurrent et connu) a pour incidence de compliquer la publication de certains articles, ce qui peut avoir pour conséquence de retarder la parution d'un numéro. Je n'ai malheureusement pas de solution miracle à proposer... La version traduite de l'anglais vers le français de ce présent questionnaire n'est pas fonctionnelle sous Windows 10 et Chrome 74.0.3729.169 (c'est pourquoi je réponds en français sur le questionnaire anglais).
U34	n/a
U35	Perhaps you need to have at least one internationally focused session that brings in the brightest starts in an area and acts as a) a tutorial for the Canadian field and b) an opportunity for students to meet researchers beyond the border.
U36	CAA GTA chapter has been quite successful. Unfortunately, for some reason, many CAA members still do not know of its existence. I don't know if this is a GTA chapter problem or a national problem? Was there an email sent to Ontario members on the national list?
U37	The bad (see above) isn't bad enough to be "ugly" just bad.
U38	Need more regional engagement. I am a member from Alberta, and I'm often learning about CAA activities/announcements from colleagues instead of receiving news from the CAA.
U39	Highly e-subscriber cost per membership
U40	N/A
U41	no ugly
U42	I'd hate to criticize a volunteer! No complaints whatsoever along these lines.
U43	How can we encourage more consultant content in our regular Journal Editions? We have a company blog containing lots of useful info and thought leadership. How could the Journal utilize information like that? How about an occasional more commercial issue which solicited materials more directly from Consultants and Suppliers. I think we did something like that a few years ago based on Geographical Regions and it seemed successful.

	More of a focus on interesting informative content rather than just academic rigor perhaps, not that academic rigor is a bad thing, but it can be exclusive of those who operate under a different business model. I believe that there is a place for joint conferences with other organizations, but excluding exhibitors may not be a good idea. Maybe the ASA gets away with it because of their sheer momentum and the existence of more technically oriented conferences/organizations in the USA. A bit long winded, but hopefully helpful.
U44	My engineering association was very disappointed when they received a very delayed response from the CAA when they were publishing an article on acoustics. The CAA's mission should include promoting the importance of acoustics throughout Canada, and this was a great opportunity for the CAA to promote itself that it lost.
U45	Nothing
U46	Given that it is a small volunteer-run organization, it would be better for all to work harder to broaden the base of people who feel sufficiently attached that they would want to volunteer for a Board role. I'm not sure how to do this but it would help ease the burden on individual board members in the long term.

Table 4. Suggestions on status and privileges of Sustaining Subscribers. Denoted by abbreviation "SS"

SS1	Allow them have voting rights
SS2	Create FOMO (fear of missing out)
SS3	Perhaps give them other incentives through educational opportunities.
SS4	advertise these companies and their products or services
SS5	-
SS6	When I was heading Scantek, I thought it was a great benefit. Yes, the person in the institution should get a separate individual (Life?) membership for herself/himself.
SS7	Advertisement
SS8	-
SS9	they could be invited to an annual workshop in which results/achievements that could of interest for companies or institutions would be presented, or at least, receive a newsletter where their support is acknowledged and presenting results obtained in Canada in identified research areas and CV of students that could be possibly recruited. (see the example of CAV-PSU [even it is a university, but this could be enlarged to a country] http://www.cav.psu.edu/Newsletters/CAVreview18.pdf)
SS10	None
SS11	No suggestions
SS12	I'm not an individual member, but I am my company's sustaining member. I do it to support the CAA. I actually have no clue what benefits there are to be a sustaining member. Asking for individual members of a sustaining member firm to pay additional fees is a bit silly. Why not consider offering a sustaining member firm additional individual memberships for some smaller nominal fee (e.g. $50).
SS13	not applicable
SS14	There is no doubt that you need to offer more incentives to the sustaining members. As you described, they get no other benefits that having their name on the back of the journal and access to it. In my opinion, and definitely my personal case, the love and support for the association are the only reason we become a sustaining member. Please note that for the same price as sustaining member, you can have almost three employees join the organization. I suggest we offer incentives like, free pass to the AWC, small advertising space (size of business card) in the journal in one of the issues, reduced or bundled rate to send up to a certain number of people to the AWC or local chapters, recognition on the AWC by advertising their logo on few stand-up banners (less than $150 per banner), small plaques to recognize them for 5, 10, 15 years of consecutive years of support (less than $50), and many more ideas.
SS15	Associate advertising or visibility with the sustaining membership, such as their logo on the back page and web ranking improvement linking CAA-ACA website or adding keywords.
SS16	no
SS17	No comments
SS18	N/A
SS19	none
SS20	.
SS21	Not sure - am not a sustaining member. Are there any other incentives except wide distribution rights?
SS22	na

SS23	Promotions. Talk to librarians as well.
SS24	Some ideas... I see from the current abstaining members that the majority are manufacturers. So a discount for conference exhibition/attendance for sustaining members is a good idea. discounted advertising in Canadian Acoustics might also be good. Preferential exhibition spots could attract more manufacturers. Logos on the back page. For the sustaining members from consultancies, maybe even more significant discounts on conference attendance when they send 3 or more attendees, for example… actually this could be a membership wide promotion. You could also have a tier-based sustaining member system (platinum, gold, silver, bronze or similar) to extract more from the larger companies.
SS25	na
SS26	I have no idea on this.
SS27	I have no suggestions
SS28	Look for ways to make it more worth the cost for a company to become sustaining subscriber. While the cost isn't high, it's hard to justify in terms of what a company gains from joining as such.
SS29	-
SS30	N/A
SS31	Offer grants for younger prospective members to join for free? they may continue being a part later on.
SS32	No change in voting status.
SS33	Leur permettre un tarif préférentiel pour la publicité. Les inviter à publier des white papers pour leurs innovations. Créer des publications communes industries/recherches pour mettre en avant les projets d'innovation d'avant-garde.
SS34	n/a
SS35	Ask all members to ensure that their universities are on board. Give free advertising in the conference proceedings for companies who are sustaining subscribers.
SS36	As above, this seems to be the same group of companies. As a tiny company, the primary benefit of being a sustaining subscriber is altruistic but there are many competing interests for a limited altruism budget. Most of the people that view the sustaining subscriber list are already in the field and know the players. Is there a mechanism to provide more exposure to sustaining subscribers (eg. CAA takes out an ad at Internoise or in JASA that includes a list of sustaining subscribers? This would both promote the acoustical work being done in Canada and provide easy contacts for those around the world.)
SS37	N/A
SS38	Make it possible for members from a sustaining subscriber company to have easier access to the journal.
SS39	Annual cost per membership (electronic and hardcopy), must be within $100
SS40	-
SS41	it seems that CAA has been quite successful for many years at retaining sustaining subscribers. I don't know how many potential sustaining subscribers are out there, perhaps a survey of acoustical companies in Canada could reveal whether there is much more to do.
SS42	More of a presence in Universities championing the (future) professional value of relevant association membership. Students become energetic, young professionals...
SS43	The Association could consider promoting sustaining and personal memberships as an implicit demonstration of expertise. There are many consultants who claim to be experts in Acoustics in Canada but are not members. That indicates some kind of a disconnect. Surely an "expert" in acoustics/vibration/noise control would see benefit in being a member of the only Canada wide Acoustical Association. Perhaps provide some incentive/encouragement for sustaining members to get as many of their employees/students to sign up as possible.
SS44	General promotion of this option is probably the most important thing, but reduced conference registration fee for 2 employees and a speed-dating event would make it very attractive for us.
SS45	I think it is important for the CAA to think about what it provides these sustaining subscribers in exchange for their membership.
SS46	I'm not sure

Table 5. Responses to question with regard to student motivation. Denoted by letter "S".

S1	Reduce their dues
S2	Free conf registration. Free beer.

S3	Sponsoring travel for students or paying registration fees for students to go to conferences in and network, present their work, and find out what the latest work in their field is. These opportunities can be hard for students to fund and are extremely important.
S4	job information and mentoring opportunities
S5	-
S6	I am too old to remember what a student wants.....besides th eopposite sex.
S7	I think 50 dollars still is high. IEEE membership is high but they offer 50 percent off one month in a year. You can set a discount like half price for one month a year like them.
S8	-
S9	Supporting small workshops for young researchers, as what is made in France with the société française d'acoustique (https://jjcab18.sciencesconf.org/, https://www.univ-brest.fr/JJCAAS2018/)
S10	Be open to varying points of view, not a mouthpiece for some only.
S11	Increase presence in universities
S12	Other than the profs in CAA who are at their school, I don't think the CAA is known at most schools. Does the CAA have a group that visits school career fairs etc? Second, make it near free for students, or free for the social event(s). Third, reach out to the career departments in schools' engineering and physics departments (particularly of the host city schools), and make sure they know. Why not have a "young professional" rate for 1-5 yrs after graduation, where membership is significantly reduced or free? Lastly, don't just focus on academics. Not every student wants to go into academia. Why not have a special session for students where they can learn about the other fields of acoustics (industry, consulting, sales, etc). (I saw you mention this below for sustaining subscribers - but why not open it to all members?) The ASA recently tried something - they paired up volunteer senior members w/ students (matched by interest) at the dinner. You should consider this. The students then to shadow their prof or their own research group. Broaden their horizons.
S13	not applicable
S14	Provide them with a heavily discounted membership fee as long as they stay active and provide a paper in their field. Encourage the manufacturers to support them to attend the AWC.
S15	Maybe it could be interesting to have an early career pricing to attend the annual conference.
S16	no
S17	We would need to advertise more at universities about the potential benefits of CAA membership
S18	N/A
S19	none
S20	.
S21	Attract: More visibility of the subject of acoustics at the undergraduate level. Retain: have activities for student members, lower (or no) membership dues.
S22	na
S23	Not an easy job considering the size of this group.
S24	expand the student membership category to student and young professionals (less than 2 yrs experience)... for example almost all of our new hires are mechanical engineers who have never heard of CAA during their student days.
S25	na
S26	Offer them better price when they sign a multiple year contract instead of one year.
S27	reach out and engage students more aggressively
S28	N/a
S29	-
S30	N/A
S31	See above
S32	Keep contacting Universities and Colleges about acoustic prizes.
S33	Les étudiants qui participent bénévolement à une activité majeure (ex: aide durant l'organisation d'un congrès, aide avec le comité éditorial) devraient obtenir la gratuité pour leur inscription. Ce serait une belle façon de reconnaître leur engagement à un prix modique pour l'association
S34	n/a
S35	Do the same as the ASA: treat students well. Minimal costs for membership, free registration at meetings and free subscription to the journal, special events for the students at the meeting.

S36	Many students (especially undergrad) do not know that societies such as CAA exist and offer free or discounted membership. CAA ad and/or articles in campus publications promoting the mission and benefits?
S37	N/A
S38	Reach out to more universities; especially those without any programs in acoustics, where students whom are interested in this field have less support.
S39	Provide library vouchers to student members which can be utilized in recognized university library centres to avail price discounts on books
S40	Section dedicated for them with employments, areas of interest, discounts to events...
S41	the retention of student members is a problem with other acoustical societies also. The problem is that students cannot always find a job in their technical area and often move away from acoustics.
S42	Same as above.
S43	See last item above
S44	I'm not sure, advertise in universities?
S45	Reduce the cost for students to attend the conference. Make the students feel like the CAA is a group that they love and want to be part of but they have to first come to the meeting. Most students can't afford the crazy registration cost in addition to the travel. Further, the historic exclusion of students at the banquet (unless they pay a separate amount for the banquet) is unfortunate and creates a tiered system. Further, I think the CAA needs to be more engaged in student outreach not just at the graduate or undergraduate student levels but reaching out to high school students and other student groups.
S46	I think you do well at it actually. Student paper competitions and awards. Is there an organized Student group like at ASA? If so, who runs it, and does its role need to be re-examined and refreshed?

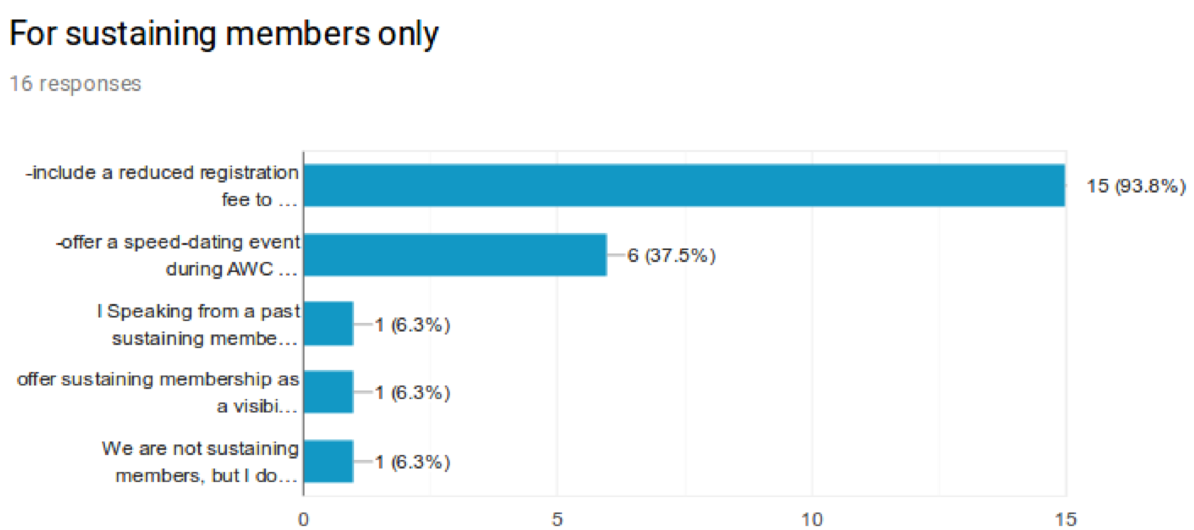


Figure 5. Responses on question regarding offers to Sustaining Subscribers to increase their involvement.

4 The Discussion

Many comments received deserve a proper follow-up.

- In some cases, the comments received clearly indicate that some information was dropped and that the respondent was unaware or misinformed. The authors, several of them being academics, strongly believe that every opportunity should be seized to inform and educate. Accordingly, these "misinformed comments" have been addressed in Section 4.1.
- In other cases, the comments received are precious suggestions and ideas that were offered to the CAA to better understand how it is doing and how it could improve the service to its members. Theses will be treated in Section 5 that summarizes the actions.
- In a -rare few occasions, the comments received were rude and disgraceful. These comments haven't been edited, and are presented as such, but is a good opportunity to mention that CAA is a voluntary-based non-for-profit association that is only running from volunteer free time devoted to advocate for acoustics.

Comments to *Misinformed* Responses from Survey

- U7, amongst others, is an interesting comment that is worth commenting. While this is true that the Acoustical Society of America (ASA) is certainly a leader in its field and could serve as an inspiration for CAA, there are nevertheless some very important differences between our two associations that explain why CAA is not just a “mini-ASA”: ASA is much older than CAA and its scientific journal, the Journal of the Acoustical Society of America (ASA) is the oldest and most cited journal in the field of acoustics. By contrast, CAA is much younger and its journal came much after its older sibling’s. JASA is unique assets and a very large source of revenues for ASA, as most libraries across the world will have to subscribe directly or indirectly to it. By contrast, CAA opted to make its Canadian Acoustics open access (after a 12 months' moving wall embargo) in compliance with the National Science and Engineering Research Council (NSERC), the Canadian Institutes of Health Research (CIHR) and the Social Sciences and Humanities Research Council of Canada (SSHRC) harmonized policy on access to research publications [1]. CAA strongly believes in opening up Canadian research to the world and even recently signed the Declaration on Research Assessment (DORA) [2] as it recognizes the need to improve the ways in which the outputs of scholarly research are evaluated. Within national acoustic societies and associations, ASA has certainly one of the largest numbers of members who benefit from direct access to the -paid- journal as well as a slight discount on -pricey-ASA conferences. By contrast, CAA’s membership is much more modest (see Figure 6 with the most recent report on membership breakout numbers) as it mostly concerns Canadian nationals. Finally, and most important, the very different financial realities of ASA and CAA cannot be understated. While ASA is capable of paying a fully staffed permanent office and secretariat, CAA has been relying exclusively for the last 40 years on volunteers and acousticians dedicated to their communities to run all aspects of its life (journal publishing, website maintenance, conference organization, outreach initiatives, etc.). This last difference is significant and also make our scientific conferences, which is really the place where we “experience” what being a member is, very different. While the ASA conferences are always very professionally executed with a very acute and topical scientific content, CAA conferences are entirely run by volunteers, accessible to all (including students and undergrads) thanks to its very low registration fees and covering with much broader topics within its conference tracks.

In conclusions, while ASA is certainly a good source of inspiration for CAA’s directors and executives, the differences between the fundamentals of our two associations also need to be taken into account. Much more realistic comparison could be made with other national associations, like the Australian Acoustical Society (AAS) [3] or Société francaise d’acoustique (SFA) [4], and CAA can be proud of its societal impact through its rich and open-access journal, as well as its friendly and accessible annual conferences.

Table 6: Break-out of CAA members as published in CAA Executive Secretary’s report on October 9, 2020, during the Annual General Assembly of the association

Subscription Type	Number
Direct Subscriber	1
Indirect Subscriber (USA)	2
Courtesy	2
Indirect Subscriber (International)	3
Indirect Subscriber (Canada)	4
Sustaining Subscriber	19
Student Member	52
Individual Member	199

5 Conclusions and Action Plan

The “Membership Task Force” has been gathering during the AWC19 events and listed a number of possible initiatives aiming to address the issues reported by the members in the “Bad” and “Ugly” comments. The table below list these proposals, shrunk to a single line statement in the left column, and each of the 10 members was then invited to give its “top 3”, with the total number of votes presented in the right column of the Table 7 below.

After discussion [5], task-force members agreed to focus on three top priority initiatives: a) enhance a practitioners’ corner in the journal welcoming non-peer reviewed contributions; b) create a permanent Social Media Editor position that would greatly enhance the CAA outreach, and c) involve the CAA in organizing student competitions and having a presence at science fairs to engage young participants.

Table 7: Break-out of CAA members as published in CAA Executive Secretary's report on October 9, 2020, during the Annual General Assembly of the association.

PROPOSALS	TOP3 VOTES
Conference	
Promote Real Life Experience (Meet people face to face)	0
Lower student fees for conference	1
Deploy referral system (bring a friend for 50%)	1
Promote student conference travel subsidies and awards.	0
Find ways to engage young faculty members (vehicle for their students) + junior champion or company representative.	4
Deploy an "under 30" membership.	0
Find a way to capture keynotes and ask for proceedings.	0
Journal	
Enhance Practitioners corner in the journal	6
Association	
Create position for Social Media Editor	10
Poach: Invest in marketing towards manufacturers and consultants.	0
Propose student competition topics to scientific fairs or schools	5
Reach out to public	0
Cross-referencing (logo and links on website)	0
Encourage local chapters / initiative	3

5.1 Creation of a "Social Media Editor" role

Comments and constructive suggestions received (presented in tables 4 and 5) received clearly show that there is room for CAA to improve its visibility, through a greater, media presence and outreach activities. To better fulfill this role, in this Internet 2.0 era, a Social Media Editor (SME) position was created in 2019 by CAA to fulfill this important role. The SME is responsible for animating all social media belonging to CAA, including and not limited to Twitter and LinkedIn accounts in order to communicate to CAA members and the general public on the following topics, with desired frequency indicated:

1. Our members in the news [as triggered by news feeds]
   Any relevant and professional news relating to a given CAA member of general interest.
2. Canadian acoustic news [as triggered by news feeds]
   Any public information broadcast my major media (CBC, etc.) related to acoustics in Canada.
3. Our sustaining members in the news [limited to one per month per sustaining member]
   Any information from our sustaining members of general interest. Such information cannot be limited to pure advertisements and should be limited to one hit per month.
4. Gems from the past [4 per year]
   A selected article or piece of information published in the Canadian Acoustics journal of great value that is worth bringing to the attention of younger readers.
5. Canadian acoustic history [2 per year]
   Any piece of information related to the history of acoustics in Canada
6. Acoustics 101 [as triggered by news feeds]
   Any piece of educative material related to acoustics, and worth reading for CAA members and general public
7. Acoustic jobs in Canada [as triggered by news feeds]
   Any job, position or internship offered or sought in the area of acoustics in Canada
8. Acoustic training in Canada [as triggered by news feeds]
   Any technical training, academic curriculum or other program on acoustics offered in Canada
9. Acoustics Week in Canada [as required]
   Any new or information related to the annual conference of CAA, including live coverage
10. Canadian Acoustics [4 per year]
    Any new or information related to the publication of a new journal issue with highlights on its content.
11. Awards and prizes [2 per year]
    Any information related to award recipients and to announcements for awards and prizes

It was agreed that the newly created position and support be set up as a two-year trial period and that the SME would report annually to a formal performance evaluation committee that would be composed of the current treasurer (Dalila Giusti), executive secretary (Roberto Racca) and past president (Frank Russo).

5.2 Re-initiating a Practitioner corner in JCAA

To make sure that JCAA keeps the momentum of being a venue that serves all our community at large, the editorial board will be happy to publish short 2-pages articles, similar to technical notes, in which practitioners can describe innovative projects and state of the art work in the world of acoustics. Authors are invited to submit their manuscript under “Practicioner Corner” section through the online system at http://jcaa.caa-aca.ca. Each manuscript will be reviewed by the Canadian Acoustics Editorial Board that will enforce the journal publication policies (original content, non-commercialism, etc., refer to Journal Policies section online for further details) while welcoming promotion of authors expertise, companies services, and consultants' success stories and the like..

Remerciements/Acknowledgments

The authors would like to acknowledge the current Board of Directors of the Canadian Acoustical Association as well as the “Membership Task Force” for its for their continuous support throughout this exercise. The CAA would also like to thank its 46 members who answered this questionnaire.

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[1] “Tri-Agency Open Access Policy on Publications - Science.gc.ca.” http://www.science.gc.ca/eic/site/063.nsf/eng/h_F6765465.html?OpenDocument (accessed Oct. 13, 2020).

[2] “DORA – San Francisco Declaration on Research Assessment (DORA).” https://sfdora.org/ (accessed Oct. 13, 2020).

[3] “Austalian Acoustical Association.” https://www.acoustics.org.au/ (accessed Oct. 13, 2020).

[4] “SFA - Société Francaise d’Acoustique - Accueil.” https://sfa.asso.fr/fr/accueil (accessed Oct. 13, 2020).

[5] R. Racca, “Minutes of the 2019 CAA Board of Directors Meeting,” *Can. Acoust.*, vol. 47, no. 4, Art. no. 4, Dec. 2019, Accessed: Oct. 13, 2020. [Online]. Available: https://jcaa.caa-aca.ca/index.php/jcaa/article/view/3366.

ACOUSTICS WEEK IN CANADA 2020

REPORT ON THE "ONE-DAY CELEBRATION" EVENT

Acoustics Week in Canada 2019
Oct 9, Everywhere (online)

Because of the COVID-19 situation, the Acoustics Week in Canada (AWC) originally planned for October 2020 in Sherbrooke (QC) has been postponed to October 2021. Nevertheless, and as a "warm up", Sherbrooke"s organizing committee had been looking into setting up a little 1-day online celebration for October 2020. This report presents the highlights of AWC2020 One-Day Celebration that took place online on October 9, 2020. The final program is presented together with some memories and comments received from participants. Olivier Robin and Jérémie Voix were actively involved in making this special day happen and particularly thankful to the support received from all round-table presenters, session presenters and moderators as well as all audience and CAA members present during the day.

1 Final program (as presented)

Time	Activity
09:00-09:10	**Welcome Note**
09:10-10:00	**Round-table** - COVID-19 Pandemic: impacts, challenges and opportunities for the CAA-ACA community Nick Laperle (EERS) Jacopo Fogola (ARPA Piemonte, Italy) Alexandre Lehman (UdeM) Moderators: Olivier Robin (UdeS), Jérémie Voix (ÉTS)
10:00-14:40	**Main Session (Timeslots within a given session might be advanced in case of no-show)** · Hearing Conservation 10:00-10:20 Moshgelani (In-Ear Audio and Speech Processing Algorithms for Digital Hearing Protectors) · Signal Processing / Numerical Methods

	10:20-10:40 F. Merli (The Roman Theatre of Verona: a different representation method of the acoustical parameters) · Architectural Acoustics 10:40-11:00 A. Bevilacqua (Acoustical measurements of the Roman theatre of Verona by mapping the sound reflections in real time) 11:00-11:20 Berardi (The evolution of the acoustics of a Medieval Church) 11:20-11:40 Berardi (VARIANCE OF REVERBERATION TIME, CLARITY, AND SPEECH TRANSMISSION INDEX IN GYMNASIUM) 11:40-12:00 Licitra (ANALYSIS OF ENVIRONMENTAL SOUND LEVELS IN ITALY DURING THE COVID-19 EMERGENCY) 12:00-12:20 Lee (The effect of sound masking on employees' acoustic comfort in open-plan offices) · Speech Sciences 12:20-12:40 Perna (Socio-phonetic tendencies and linguistic aspects of English Contemporary Commercial Music) 12:40-13:00 Al-Zanoon (Investigation of motor equivalence and tongue muscle excitation patterns in simulated English vowels · Engineering Acoustics / Noise Control / consulting 13:00- 13:20 Berardi (Design and experimental validation by 3d printing of a permeable silencer metamaterial) 13:20-13:40 Dumoulin (Noise from outdoor live events in downtown Montreal: regulatory framework, complaints management and predictions tools) 13:40-14:00 Iannace (MINI-WIND TURBINE NOISE INSIDE HOME) 14:00- 14:20 Chao (Development of a mobile full face tracking system during speech production)
14:20-14:50	**Coffee Break** in "Wonder" online app
14:50-16:05	**Student Pecha-Kucha Presentations** 14:50-15:05 Lucas Einig (HPD Fit-Testing Feature developed within a Hearing-Care Platform for Musicians) 15:05-15:20 Daniel Nault (Direct manipulation of variability in the auditory feedback system via real-time formant perturbation) 15:20-15:35 Benesch ("Listen to Your Heart": Exploring the Link between In-Ear Audio and Emotions)

	15:35-15:50 Roujan Khaledan (Evaluating the Accuracy of Lip Motion Tracking Using Surface Scanning Face Tracking Technology)
15:50-16:15	**Coffee Break** on “Wonder” app (see Figure X)
16:15-16:45	**Acoustical Gems** 16:15-16:25 Olivier Robin - Resources for online acoustics and vibration 16:25-16:35 Noise Busters - a sound and vibration podcast 16:35-16:45 The Lockdown Musical: NASA SpaceApps Global Winners 2020
16:45-17:00	**Award Ceremony**
17:07	**Group Picture** (see Figure X)
17:00-18:00	**Annual General Assembly**: open to all CAA members. 17:05 Family picture let's all open our cameras and smile for posterity!

2 Final program (as presented)

Some -anonymized- comments received by email; their respective authors will recognized themselves:

From An old-timer from CAA:
To start with, CONGRATULATIONS for a fantastic conference yesterday. To tell you the truth, I wasn't optimistic about it. I was ready to sleep through half of it. However, the reality was so interesting that I didn't. The organization, presentation, timing, everything was perfect to me! So, once more, congrats to you and the organizing team!

From a new-timer to AWC:
I'm honoured for having taken part in this wonderful event, which I noticed has gathered a lot of people from everywhere:) I hope I'll be able to continue with this work, always in a professional and clever way.
Again, this has been a very good occasion for me to let other people know my research, and it was 100% thanks to you, so I'm very grateful:)

Some young members you may recognize
Thank you for giving us an opportunity to talk about our project "The Masked Scales" at the Acoustics Week in Canada event last week. We enjoyed the experience and the words of encouragement we received from the audience.
We are happy we were able to share our joy our merging science, coding, and music.

Some other fellow acousticians
Thank you so much for allowing virtual attendance this year! This conference is always so inspiring and motivating to see the work others have been doing. Will you be sharing parts of the conference recording at all? There were a couple presentations in the architectural acoustics section I missed due to project meetings, and would love to get the chance to re-watch those. Thanks again and all the best.

3 Some memories

3.1 Virtual coffee breaks

AWC2020 One Day Celebration included a “virtual coffee break” where people happy to regroup in these “virtual bubbles”: as soon as a person’s avatar is close enough to other avatars, the video connection pops-up. Here, in figure 1, 3 long-time members of CAA are chitchatting and discussing the merit of different bear sizes.

Figure 1: Overview of one AWC2020 virtual coffee break

3.2 Virtual coffee breaks

Despite the distance, the whole family was there (well almost, sorry for the missed screenshot of the 3rd page of Zoom attendants!). See Figure 2 and 3 below.

Figure 2: AWC2020 Family Picture – Part I

Figure 3: AWC2020 Family Picture – Part II (sorry for missing 3rd page!)

3.3 A well-rated event

Quick surveys launched during the event showed a good level of satisfaction amongst AWC2020 audience. Surveys and results are shown in figure 4.

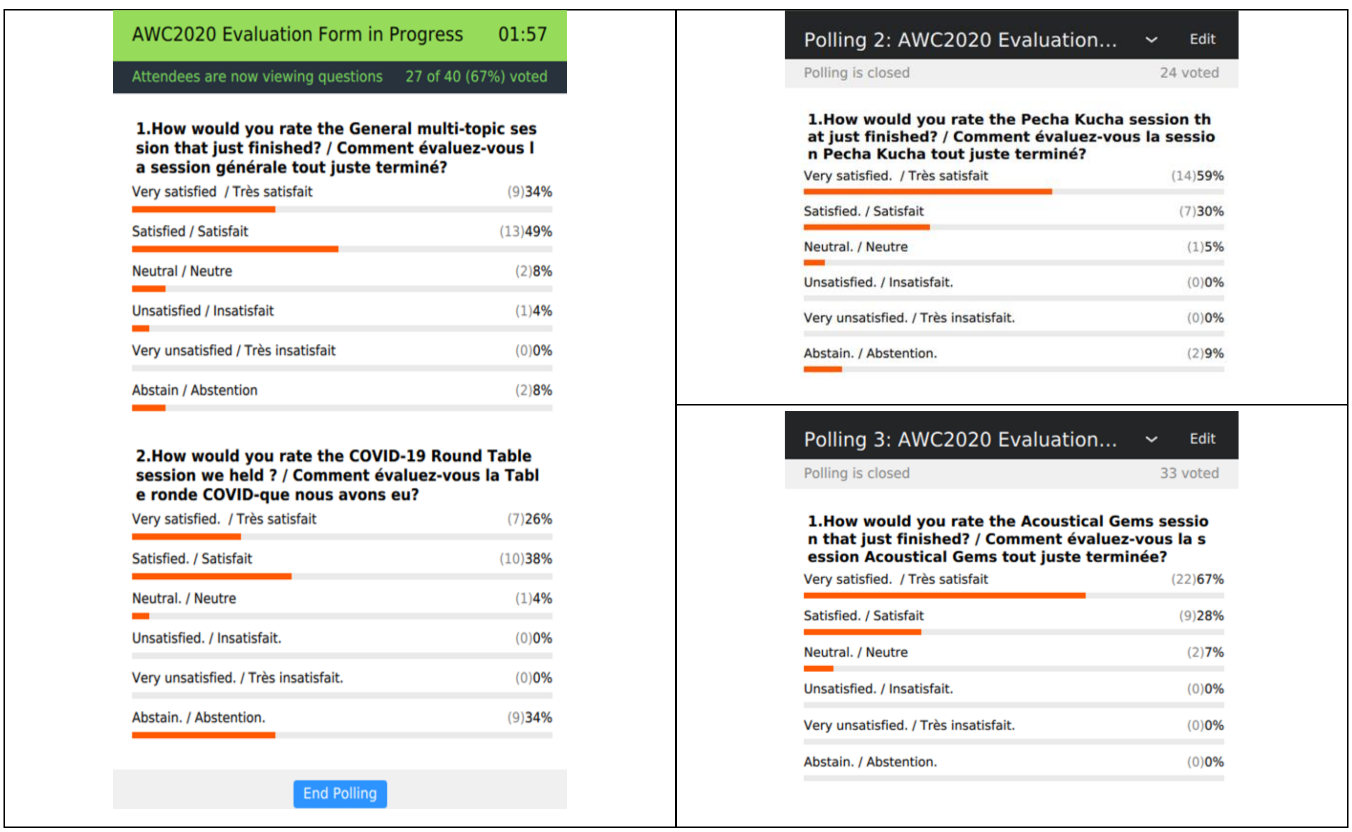


Figure 4: AWC2020 Evaluation forms and questionaires

3.4 A well-attended event

The online attendance, shown in figure 5, varied over the day, peaking at 60 people around midday. A slight turnover was noticed, and the total number of people who connected (excluded our infamous Zoom bombers that were mostly popping-up with each post on Twitter by our Media Editor) probably reached 80 persons, making it a reasonable event given the current challenges.

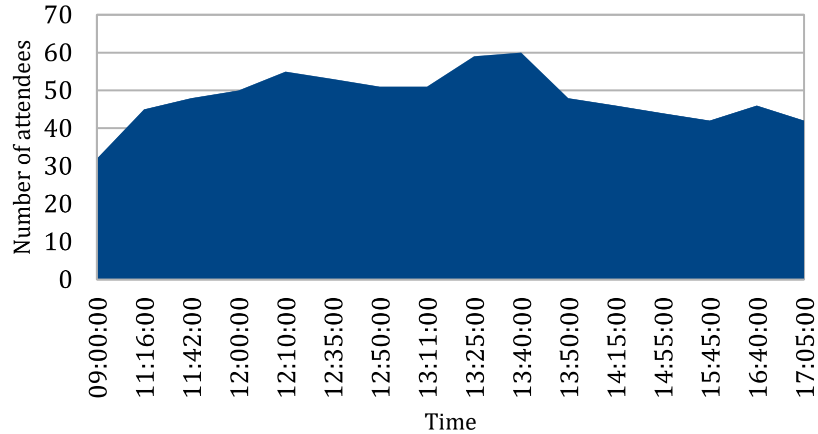


Figure 5: AWC2020 online audience

3.5 Social media presence

As presented in figure 6, this AWC2020 One-Day Celebration was visible on many social media and attentive readers that were present during the event will notice the high level of correlation between these live post on Twitter and the appearance of Zoom bombers in AWC2020 events! :-)

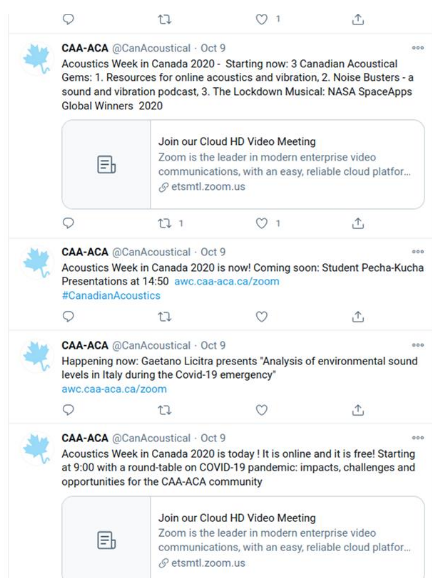


Figure 6: AWC2020 online presence on Twitter

Canadian Acoustical Association
Association Canadienne d'Acoustique

2020 PRIZE WINNERS / RÉCIPIENDAIRES DES PRIX 2020

BELL GRADUATE STUDENT PRIZE IN SPEECH COMMUNICATION AND HEARING /
PRIX ÉTUDIANT BELL EN COMMUNICATION VERBALE ET AUDITION

Yadong Liu (University of British Columbia)

FESSENDEN GRADUATE STUDENT PRIZE IN UNDERWATER ACOUSTICS /
PRIX ÉTUDIANT FESSENDEN EN ACOUSTIQUE SOUS-MARINE

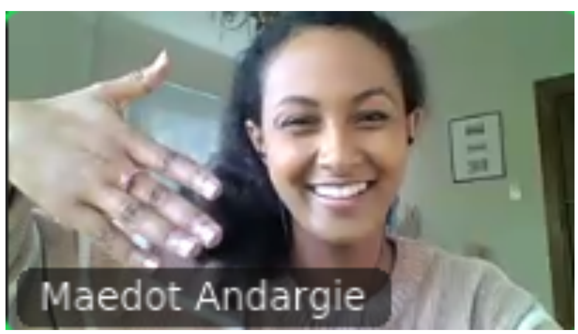
Alexander Slonimer (University of Victoria)

Eckel Graduate Student Prize in Noise Control /
Prix étudiant Eckel en Controle du Bruit

Yu Luan (École de Technologie Supérieure)

Thomas D. Northwood Student Prize in Architectural and Room Acoustics /
Prix étudiant Thomas D. Northwood en Architecture et Acoustique des Salles

Maedot Andargie (University of Toronto)



Raymond Hétu Student Prize in Acoustics /
Prix étudiant Raymond Hétu en Acoustique

Eric Cui (University of Toronto)

CONGRATULATIONS / FÉLICITATIONS

Canadian Acoustical Association
Association Canadienne d'Acoustique

PRIZE ANNOUNCEMENT • ANNONCE DE PRIX

CANADIAN ACOUSTICAL ASSOCIATION
ASSOCIATION CANADIENNE D'ACOUSTIQUE

Prize

EDGAR AND MILLICENT SHAW POSTDOCTORAL PRIZE IN ACOUSTICS
ALEXANDER G. BELL GRADUATE STUDENT PRIZE IN SPEECH COMMUNICATION AND HEARING
ECKEL GRADUATE STUDENT PRIZE IN NOISE CONTROL
FESSENDEN GRADUATE STUDENT PRIZE IN UNDERWATER ACOUSTICS
RAYMOND HÉTU UNDERGRADUATE STUDENT PRIZE IN ACOUSTICS
THOMAS D. NORTHWOOD GRADUATE STUDENT PRIZE IN ARCHITECTURAL AND ROOM ACOUSTICS
ALBERT S. BREGMAN GRADUATE STUDENT PRIZE IN PSYCHOLOGICAL ACOUSTICS

Prix

PRIX POST-DOCTORAL EDGAR ET MILLICENT SHAW EN ACOUSTIQUE
PRIX ÉTUDIANT ALEXANDER G. BELL EN COMMUNICATION ORALE ET AUDITION (2E OU 3E CYCLE)
PRIX ÉTUDIANT ECKEL EN CONTRÔLE DU BRUIT (2E OU 3E CYCLE)
PRIX ÉTUDIANT FESSENDEN EN ACOUSTIQUE SOUS-MARINE (2E OU 3E CYCLE)
PRIX ÉTUDIANT RAYMOND HÉTU EN ACOUSTIQUE (1ER CYCLE)
PRIX ÉTUDIANT THOMAS D. NORTHWOOD EN ACOUSTIQUE ARCHITECTURALE ET ACOUSTIQUE DES SALLES (2E OU 3E CYCLE)
PRIX ÉTUDIANT ALBERT S. BREGMAN EN PSYCHOACOUSTIQUE (2E OU 3E CYCLE)

Deadline for Applications:

April 30th 2021

Date limite de soumission des demandes:
30 Avril 2021

Consult CAA website for more information
Consultez le site Internet de l'ACA pour de plus amples renseignements
(http://www.caa-aca.ca)

Announcement

ACOUSTICS WEEK IN CANADA

Sherbrooke (Québec) October 6-8, 2021

View of Mont-Orford from downtown Sherbrooke

Following its report in 2020, Acoustics Week in Canada 2021 will be held on October 6-8, in Sherbrooke, Québec.

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

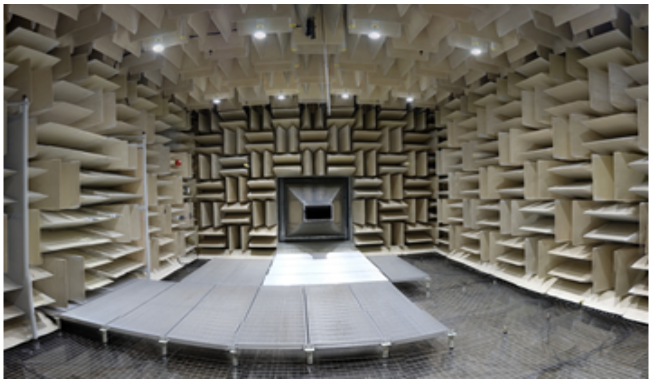
Plenary, Technical and Workshop Sessions are planned throughout the conference. Each day will begin with a keynote talk of broader interest and relevance to the acoustics community. Technical sessions are planned to cover all areas of acoustics including:

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

Conference Chair:
Olivier Robin
(Olivier.Robin@USherbrooke.ca)

Technical co-Chairs:
Patrice Masson and
Sebastian Ghinet
(Patrice.Masson@USherbrooke.ca)
(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).

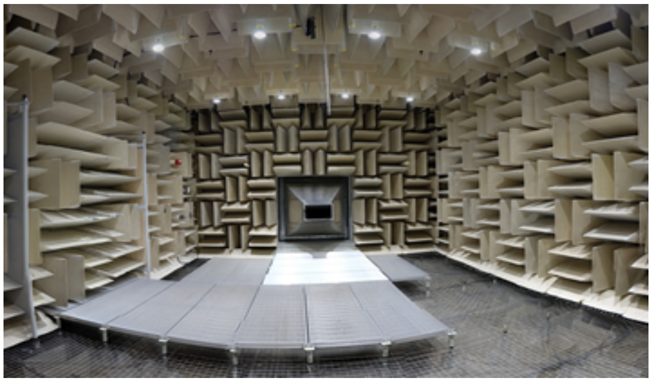
Lieu et hébergement – La conférence aura lieu au Centre de congrès de l'Hôtel Delta Sherbrooke. Un bloc de chambres dans l'hôtel sera disponible à un tarif spécial. Des passes de bus seront offertes à tous les participants afin de favoriser l'usage du transport en commun durant la conférence. Une navette 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 évènement 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 évènements 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
(Patrice.Masson@USherbrooke.ca)
(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 ACOUSTICAL ASSOCIATION

Minutes of the Board of Directors Meeting

Thursday, October 8th, 2020 2:00 PM – 4:30 PM (EDT)
by Zoom videoconference

1. Call to Order

Meeting called to order 14:05 (EDT)

Present online: Jérémie Voix (chair), Alberto Behar, Umberto Berardi, Bill Gastmeier, Bryan Gick, Michael Kiefte, Andy Metelka, Hugues Nélisse, Roberto Racca, Frank Russo, Mehrzad Salkordeh.

Agenda approved: Moved by Jérémie.

2. President's Report (Jérémie Voix)

Jérémie reported that following the resignation of the CAA systems administrator on 13 March, he and Cécile Le Cocq handled the migration of the journal and subscription site to the latest version of the Open Journal System (OJS). They made the decision to have OJS hosted and supported externally as a cloud service, which enabled various issues to be addressed cost effectively. The migration involved both the permanent journal site and the yearly instantiated AWC (Acoustics Week in Canada, the CAA's annual conference). As part of the transition the bug-prone existing e-mail module was replaced with a reliable custom version. In parallel, there is an ongoing effort to configure the CAA bulk and automated emails to make them more acceptable to spam filter heuristics (e.g. avoid "sender envelope" not matching actual issuer of the email). This should alleviate the problem of members not receiving important notices such as renewal reminders because they are trapped by their spam blockers.

An initiative to rebuild the dwindling membership numbers caused by missed or failed renewals (and past difficulties in creating new ones online) has been rolled out. The recovery plan consisted of the reinstatement in July of all memberships lapsed in the previous year to good standing until the end of 2020 and the extension of then current ones by 5 months to provide a recognition and equivalent benefit to members who had kept up with their renewals. Further details on the effect of this initiative are provided in the Secretary's Report. In parallel, an outreach action to sustaining subscribers is aimed to countering a substantial decline in their numbers. A Task Force created to investigate issues of membership / sustaining subscription value and relevance has conducted a questionnaire-based survey and analyzed its results, which will be soon published as an article in Canadian Acoustics.

The search is still ongoing to recruit a Standards Committee Coordinator to fill the role of the late Tim Kelsall. Alberto Behar has generously been acting as interim coordinator but must be relieved of this incumbency. Bill Gastmeier mentioned that the standards related activities within the CAA may overlap with CSA and ISO initiatives within Canada, and possibly there is a rationale to align or integrate the CAA committee with the CSA. It was agreed that this should be taken into consideration, and Jérémie will solicit input in the matter. Hugues Nélisse pointed out that in some cases "ad hoc" committees are indeed expected to retain independence from official standards organizations to act in a critiquing role.

AWC 2020 AGM: organization discussion.

To be held online as part of AWC20 Celebration Day, 9 Oct 2020 at 17:00 EDT
Voting could be required if there are nominations from the floor; Zoom enables voting tools for this purpose. All current Board members have indicated that they would stand for reconfirmation. It was agreed that Jérémie would first propose reconfirmation of the full slate and the procedure would move into a vote if the proposal met with objections from the floor.

AWC 2020 Celebration Day: final organization.

- Welcome Note
- Round table on COVID-19 repercussions on the acoustics world.
- Student Pecha-Kucha presentations
- Acoustical Gems
- Award Ceremony
- AGM (Jérémie, Roberto and Umberto will be presenting reports)

3. Treasurer's Report (Dalila Giusti)

Dalila could not attend the meeting so her report will be circulated and discussed offline.

4. Awards Report (Joana Rocha)

In Joana's absence, Jérémie ran through her report of awarded prizes; there were no comments or issues raised. Only one student presentation prize will be awarded at the AWC 2020 online event given the smaller than usual number of presenters due to the compressed format.

5. Editor's Report (Umberto Berardi)

Umberto reported publishing difficulties with the printing company's unresponsiveness which is delaying the production and mailing of the September issue. On the editorial side, recent submissions of articles ensure a well populated December issue and material into 2021, so journal content is in good shape. Financially the journal is well within budget due to a comparatively slim September issue (without the substantial contribution of proceedings papers in normal AWC years) lowering expenditure; advertising revenue is good, still boosted by full page advertisers who signed on at the journal stand at the ICSV congress in Montréal last year).

Non-delivery of journal issues is reported occasionally by various indirect subscribers (institutional libraries) through their subscription agencies, and make-up copies are sent from reserves that Umberto keeps aside; the intent in the future would be to move ahead with eliminating the archive and transition to print on demand to fulfill any request for back-issues.

Umberto noted that the journal is still short of editorial board members and reviewers especially in the areas of physical and underwater acoustics, for which he is actively searching and recruiting. Andy Metelka offered help in making contacts. Lastly, Umberto indicated that a statement about the journal's universal open access policy and adherence to DORA (Declaration on Research Assessment) will be published as part of the editorial page in the December issue.

6. Secretary's Report (Roberto Racca)

Roberto began by presenting the tally of memberships at latest count: 198 regular and 52 student members, showing a marked increase in numbers (about doubled) from the low point reported at the April 2020 Board meeting. This apparent resurgence, he noted, is a direct consequence of the initiative of reinstating and extending memberships that Jérémie described in the President's Report; the expectation and strategy however is that by providing what amounts to a "stimulus package" the Association will succeed in reconnecting with members who might have lapsed either due to lack of notification (email issues), or difficulties renewing because of current circumstances. For the approach to succeed, Roberto explained, it will be key to ensure that renewal notifications emails are duly delivered by the end of December when the reinstated memberships are due to expire – and to appeal and follow up with members as required. As for sustaining subscribers, given the smaller size of that group a more targeted and personal approach is planned: as a start all such subscriptions that lapsed in 2020 to date were extended to 31 December; this is to be followed by direct contacting of all recent sustaining subscribers to engage them and seek their continuing support.

In the ensuing discussion of how to better engage and motivate the CAA membership and supporters Andy Metelka inquired about considering joint activities and benefits with other organizations such as the Acoustical Society of America (ASA). Roberto agreed on the merit of extending the CAA's horizons; he noted however that the size and might of the ASA would make most collaborations somewhat lopsided as shown by the occasional joint annual meetings of the two societies where the CAA's identity is hard to evidence. Still, international collaborations and joint ventures are regarded as beneficial by the Board and Jérémie noted the potential of newly developing cultural links with European acoustical organizations.

7. Upcoming Meetings

AWC 2021: Sherbrooke (Olivier Robin, who joined as guest at 15:30 (EDT))

Olivier opened with remarks on the organization of the online event of the next day, which could potentially be a paradigm for 2021 if due to ongoing impact from COVID-19 the regular AWC could not go ahead. Currently there are no financial commitments (hotel etc.) that could not be cancelled if the pandemic were not abated by autumn 2021. Jérémie mentioned the possibility of a hybrid format where participant more local to the event region could meet in person and all others join online; the paradigm of having multiple small local clusters assembled in different locations joining online does not seem beneficial given the logistic complexity. A final decision on the format of the 2021 event will be debated and voted on at the April 2021 CAA Board meeting.

AWC 2022: St-John’s (Benjamin Zendel & Len Zedel)

Frank Russo reported that the organizing team is working efficiently in collaboration and some of the basic infrastructure is being planned to an adequate extent for this early stage of the process.

AWC 2023 Ottawa (Joana Rocha)

No updates.

ISO TC43 Montréal 2023 (Jérémie Voix)

On track for successful convening.

AWC 2024 Okanagan region? (No organizer identified)

No updates.

AWC 2025 Ryerson? (Umberto Berardi)

Still very preliminary; no updates.

8. Social Media Editor Report (Romain Dumoulin)

Romain submitted a report in absentia; Jérémie indicated that he has now moved from McGill to an industry position but intends to continue in his role with the CAA. Statistics for LinkedIn and Twitter indicate good buildup of following. Romain has been reposting numerous acoustics related items of information, generating good interest in the audience. There is a plan to create original content e.g. for “Gems from the past” and “Canadian acoustics history” in collaboration with the Journal editorial team. It was noted that given Romain’s new commercial position there might have to be guidelines in place to avoid any perception of self-support or conflict of interest in the content posted. Members of the Board expressed full confidence in Romain’s integrity and endorsed his ongoing role; oversight can be exercised on a casual basis.

9. Varia

Alberto Behar reiterated that the Membership Task Force would endeavour to have the article created from the survey results ready for publication in the December issue of Canadian Acoustics.

Umberto inquired about rules of engagement for the online presentations the next day to avoid or mitigate intrusion by disruptors; Jérémie confirmed that the meeting would default to unmoderated screen sharing for convenience, but he could block any undesired content if needed. Also, if any online voting were to take place for election to the Board it would have to be limited to confirmed CAA members.

10. Next meeting: 15 April 2021 @ 14:00 (EDT), online

Agreed tentatively on the date pending query of Board members not in attendance.

11. Motion to Adjourn

Moved by Alberto Behar; seconded by Roberto Racca.
Meeting adjourned at 16:00 (EDT).

CANADIAN ACOUSTICAL ASSOCIATION

Minutes of the Annual General Meeting
Friday, October 9th, 2020 5:00 PM – 6:00 PM (EDT)
by Zoom videoconference

1. Call to Order

Meeting called to order 17:09 (EDT) by Jérémie Voix (President),

Jérémie Voix began by acknowledging the contribution of several members of the Board and Executive on the call as well as the invaluable assistance of Cécile Le Cocq, journal manager, in bringing Canadian Acoustics to press every quarter. He also mentioned that because of the current unavailability of the CAA's treasurer Dalila Giusti due to a professional obligation, the budget had not yet been reviewed and approved by the Board and would therefore not be presented.

About 25 people in attendance online.

After a brief outlining of the AGM agenda, adoption moved by Jérémie Voix, seconded by Mehrzad Salkordeh.

2. President's Report (Jérémie Voix)

Jérémie gave an overview of the challenges that were faced over the year by himself and Cécile Le Cocq in maintaining the systems infrastructure on which the journal, conference and membership portals are hosted – especially without the assistance of a system administrator who cold no longer dedicate time to the task. The most substantial task was to maintain the Open Journal System (OJS) platform that is key to the submission, editing and publication process for Canadian Acoustics; this was greatly simplified in a cost effective manner by migrating to a cloud hosted version with a commercial provider guaranteeing uptime, backups, updating and support of the environment. The migration took a substantial effort but in the process various shortcomings of the earlier system were addressed, from problems with the emailing module to a long standing bug that had frustrated the ability of prospective new members to join the CAA online and required manual interventions in various cases. An effort to align the structure of bulk and automated emails from the Association to its members with the most current standards is still underway; hopefully that will result in a much lesser incidence of blocking of emails by spam filters.

A membership recovery initiative has taken place earlier in the year to counter a critical loss in numbers. Jérémie explained how the CAA executive felt that a combination of technical difficulties with the membership site and the preoccupations of the pandemic had likely impacted people's recollection or capacity to renew, and that it would be appropriate for the Association to extend support to its member base through a relief plan. This was rolled out in July by the automatic reinstatement until end December of all memberships that had lapsed in the previous year, and the addition of five months to the validity of memberships current at the time; email notifications also went out to all members affected. Jérémie deferred to the Secretary's Report further details on the initiative and its effect.

Jérémie informed the membership that the Association has been looking for a Standards Committee Coordinator to fill the role of the late Tim Kelsall. Alberto Behar, who has generously acted as interim coordinator, should dee his role filled on a definitive basis. He appealed for any expression of interest or suggestion and pointed members to the relevant CAA web page for information on the Committee and its activities.

Lastly, Jérémie mentioned the work of a Membership Task Force assembled to identify, mostly through a questionnaire survey sent out in June to the broad Association base, the aspects of membership that are relevant and motivational for people to join and be engaged. He stressed particularly the vital importance to the CAA of sustaining subscribers, institutional or corporate entities who choose to contribute to the advancement of the Association through higher annual dues. The findings of the Task Force and an action plan are being finalized and will be published as an article in the December issue of Canadian Acoustics.

3. Secretary's Report (Roberto Racca)

Roberto opened his remarks by pointing out that his role's main focus, during a period when technical problems hampered the CAA's online membership platform and affected successful email delivery, had been to provide the most open and helpful possible contact for members faced with renewal issues or related difficulties. That notwithstanding it was clear that the situation had led to considerable drop in membership numbers; preoccupations with and impact from the pandemic on people's lives and work likely had exacerbated attrition as the year progressed. He echoed Jérémie's earlier message that individual members and sustaining subscribers truly are the lifeblood of the Association and its activities, adding his gratitude for the steadfast support that many have provided over the years.

He then went on to summarize the substantial drop in membership and subscription numbers that had taken place in the early part of 2020 and had been brought to the attention of the Board at its April meeting. The situation brought to the decision already described by Jérémie to introduce essentially a "stimulus package" to inject new activity in the Association ranks through both the reactivation of recently lapsed memberships to last until the end of December, and the free extension of current ones by five months. A similar reinstatement was introduced to assist recently lapsed sustaining subscribers, whose decision not to renew might have been a consequence of current economic uncertainty. Roberto showed how the reactivation plan had impacted the totals especially for individual memberships which almost doubled in active number from their April low, to 250 between regular (198) and student (52) members.

In summing up, Roberto made the point that a lasting benefit from this relief measure will only be realized if the Association succeeds in engaging its reinstated members and sustaining subscribers so that they will feel motivated to renew come the end of December (or any time before). He appealed to the audience to be alert to renewal notices and aware of the possibility that they might be quarantined by oversensitive email blockers in the current climate of rampant email threats. He closed by exhorting members to follow the CAA's digital media platforms (web and social networks) where valuable information and notices are regularly posted, and not to hesitate to contact him with any questions, comments, and suggestions.

4. Awards Report (Joana Rocha)

Having just officiated the awards granting ceremony online immediately prior to the AGM, Joana limited her intervention to mentioning the current intent of the Association to explore the creation of new awards and noting that she would be proposing some ideas to the directors and executive in the coming months.

5. Social Media Editor Report (Romain Dumoulin)

Jérémie spoke on behalf of Romain, beginning with a brief overview of the role of Social Media Editor that had been announced at the previous AGM as the centralizer of all the Association's web and social networks postings. He went on to present some statistics from Romain's report showing the standing of the CAA's accounts on LinkedIn and Twitter, both of which have increased by 15-20% in following over the past year with steady posting activity. Jérémie noted that Romain's role includes the moderation of any potential content to ensure that it is factual and free from open commercialism. The content developed or selected for posting is organized in specific categories to give it a well-structured form; categories include "CAA members (and sustaining subscribers) in the news", "Canadian acoustics news", "Gems from the past", "Canadian Acoustics history", "Acoustics 101", "Acoustics jobs", "Acoustics training", "Acoustics Week in Canada", and more. Lastly Jérémie mentioned for full transparency that Romain had recently transitioned from an academic position at McGill to a private consultancy and that safeguards would be in place against any perception of conflict of interest in his role, though he vouched also on behalf of the Board for his well-proven reliability and integrity.

6. Questions & Comments from the Floor

Jérémie opened the meeting to questions and remarks from the floor as some messages had been entered on the chat line.

- Kathy Pichora-Fuller asked what had come of an award in honour of John Bradley, which had been debated at the time when she was a member of the Board of Directors but seemingly had not progressed. The question prompted interventions by long-standing Board members in attendance who recalled that after considerable mediation efforts, the process had been abandoned due to difficulties with the conditions under which the funding by the prospective donor would have been provided. It was also noted by some that the idea of an award honouring John Bradley has great merit, and ways should be sought to realize it.
- Kathy also inquired about the category of Emeritus Member which appeared in membership tallies with only a single count; Jérémie indicated that it was a legacy classification not currently used, but he would take an action item to look at

what the original motivation could have been. Kathy suggested that the CAA adopt the model of other professional organizations who offer to retired members still active in the field a limited set of privileges for a reduced or no fee; this would keep older members engaged and provide advantages from mentorship to potential donations. Jérémie noted the point and mentioned that this fits well with current discussions about introducing membership levels such as fellow as special recognition; Annabel Cohen intervened to point out that the emeritus and fellow categories fill different roles and should be considered separately, to which Kathy concurred and reiterated the importance to cater to all demographics. Roberto noted that such subjects are regularly discussed at Board meetings; he cited the recent difficulties the CAA has faced in retaining its core membership as reason for having focused more on the fundamentals, but expressed confidence that these very valid suggestions will be addressed in the near term.

- Kathy commented on how the online format of this day's events had enabled people to attend who might not have been able to afford the travel costs and time for a conventional on-site meeting. She advocated a continuing emphasis on remote participation as a means of broadening accessibility to the activities of the Association and thus helping to secure and retain the engagement of a larger spectrum of membership.
- Bill Gastmeier suggested, and Kathy supported, that the CAA should also consider increasing its funding base by encouraging planned giving among its members and patrons – especially in support of legacies such as awards and scholarships for upcoming generations of acoustics experts.

7. Upcoming Meetings

<u>AWC 2021: Sherbrooke, QC</u> (Chair: Olivier Robin)

Olivier expressed his wish that by autumn of 2021 the COVID-19 crisis will have receded to the point that a full in-person meeting will be possible just like before the pandemic, but recognized that at this point only cautious hope is possible. The intent under optimal conditions is still to have a physical meeting at the same venue and with the same level of dissemination of knowledge from the acoustics research group at Sherbrooke University through site visits. The situation will be assessed in consultation with the CAA Board of Directors in April and a decision will be made on whether to proceed with planning a fully physical meeting or a hybrid format. He noted how the organizing of the one-day virtual event now winding down had been a most valuable training for how to handle the technology and structure of an online meeting of this nature.

Both Alberto and Jérémie expressed great satisfaction at how the day's "exercise" had played out, Jérémie also noting that the coordination between himself and Olivier to make the event come together had been limited by busy schedules and other commitments, which bode encouragingly in case the 2021 conference required a similar undertaking. Olivier agreed and stated in conclusion that he and his committee would be ready to handle any possibility, from a fully physical event to a hybrid format to a wholly virtual meeting if need be. Jérémie thanked him on behalf of all participants for having had the vision to encourage and spearhead holding this one-day "acoustics celebration" after the Board rescheduled AWC to 2021.

<u>AWC 2022: St-John's, NL</u> (Co-chairs: Benjamin Zendel & Len Zedel)

Jérémie reported that the local team was willing and prepared to hold the event in 2022 and the hotel venue was secured.

<u>AWC 2023: Ottawa, ON</u> (Chair: Joana Rocha) – Preliminary commitment.

<u>ISO TC43 Montréal 2023</u> (Jérémie Voix) – On track for successful convening.

<u>AWC 2024: Okanagan Valley, BC?</u> – No committee (would be local or nearby based) or plans yet.

<u>AWC 2025: Toronto, ON @ Ryerson?</u> (Chair: Umberto Berardi) – Still very preliminary.

8. Election of the Board

Jérémie informed the AGM that of the Board members serving on four-year terms none were slated specifically for replacement or reconfirmation this year, and all were willing to stay on. Noting the challenge of holding a vote in the current online meeting format he moved that as default action the current Board be reconfirmed in its entirety. Roberto seconded, and the motion passed unanimously by show of hands. Jérémie thanked the directors for their ongoing dedication and service and declared the Board reconfirmed.

9. Varia

Kathy Pichora-Fuller mentioned that the World health Organization had intended to launch the first World Hearing Report the past May but because of the pandemic had postponed the event to 3 March 2021, World Hearing Day. She indicated that numerous academics were working with the WHO to build strong momentum behind the report and induce countries to take action to prevent hearing loss through noise management and other initiatives germane to the interests of the CAA. She suggested the Association consider participating in related activities taking place in various Canadian cities; as an example, she mentioned the global conference of the International Federation on Aging to be held in Niagara in November 2021, which will feature a strong message about the importance of hearing and acoustics for healthy aging. Jérémie committed to engaging a dialogue on how to engage the CAA in these initiatives and asked Kathy to forward any pertinent materials to him.

10. Next AGM

Jérémie noted that AWC 2021, whether physically in Sherbrooke or in some other format, would be held from the 12 to the 15 of October 2021. Based on the typical scheduling, therefore, the next AGM will be held on **Thursday 14 October 2021**.

11. Motion to Adjourn

Moved by Alberto Behar, seconded by Peter VanDelden.
Meeting adjourned at 18:08 (EDT)

CANADIAN ACOUSTICS 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 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

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 2021

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.

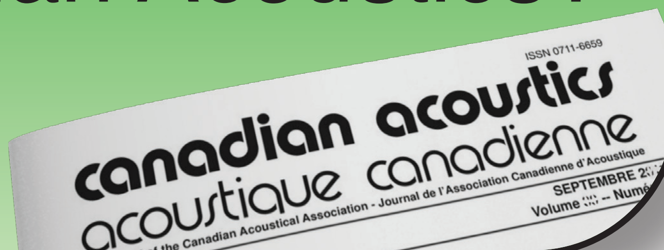
May 3rd 2019

Situation COVID-19

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.

May 13th 2020

Why publish in Canadian Acoustics?



Because, it is...

- A respected scientific journal with a 40-year history uniquely dedicated to acoustics in Canada
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- Une revue respectée, forte de 40 années de publications uniquement dédiée à l'acoustique au Canada
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- Une alternative intéressante pour une évaluation par les pairs, fournissant aux auteurs des commentaires pertinents, objectifs et constructifs

Application for Membership

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.

Subscriptions to *Canadian Acoustics* *or* Sustaining Subscriptions

Subscriptions to ***Canadian Acoustics*** are available to companies and institutions at a cost of $120.00 per year. Many organizations choose to become benefactors of the CAA by contributing as Sustaining Subscribers, paying $475.00 per year (no voting privileges at AGM). The list of Sustaining Subscribers is published in each issue of ***Canadian Acoustics*** and on the CAA website.

Please note that online payments will be accepted at http://jcaa.caa-aca.ca

Address for subscription / membership correspondence:

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City/Province ______________ Postal Code __________ Country ______________

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Areas of Interest: (Please mark 3 maximum)

1. Architectural Acoustics
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For student membership, please also provide:

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(University) *(Faculty Member)* *(Signature of Faculty Member)* *(Date)*

I have enclosed the indicated payment for:
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Corporate Subscriptions (4 issues/yr)
[ ] $120 including mailing in Canada
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Executive Secretary, Canadian Acoustical:
Dr. Roberto Racca
c/o JASCO Applied Sciences
2305–4464 Markham Street
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