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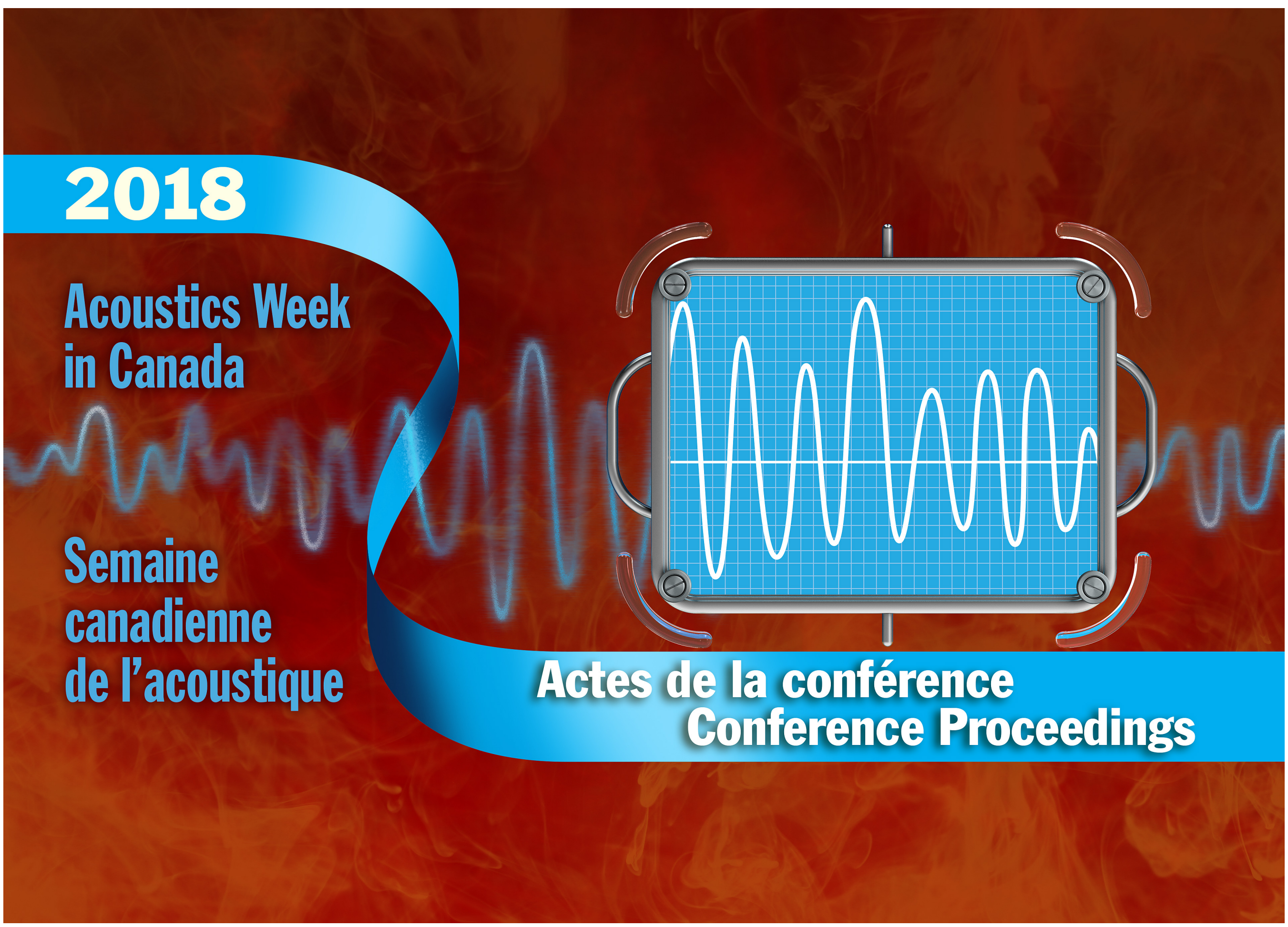

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Canadian Acoustics publishes refereed articles and news items on all aspects of acoustics and vibration. Articles reporting new research or applications, as well as review or tutorial papers and shorter technical notes are welcomed, in English or in French. Submissions should be sent only through the journal online submission system. Complete instructions to authors concerning the required "camera-ready" manuscript are provided within the journal online submission system.

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Canadian Acoustics is published four times a year - in March, June, September and December. This quarterly journal is free to individual members of the Canadian Acoustical Association (CAA) and institutional subscribers. Canadian Acoustics publishes refereed articles and news items on all aspects of acoustics and vibration. It also includes information on research, reviews, news, employment, new products, activities, discussions, etc. Papers reporting new results and applications, as well as review or tutorial papers and shorter research notes are welcomed, in English or in French.The Canadian Acoustical Association selected Paypal as its preferred system for the online payment of your subscription fees. Paypal supports a wide range of payment methods (Visa, Mastercard, Amex, Bank account, etc.) and does not requires you to have already an account with them. If you still want to proceed with a manual payment of your subscription fee, please use the application form from the CAA website and send it along with your cheque or money order to the secretary of the Association (see address above). - Canadian Acoustical Association/Association Canadienne d'Acoustiquec/o JASCO Applied Sciences2305–4464 Markham StreetVictoria, BC V8Z 7X8 Canada - - - secretary@caa-aca.ca - Dr. Roberto Racca

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 d'utiliser le formulaire d'adhésion du site de l'ACA et de retourner ce dernier avec votre chèque ou mandat au secrétaire de l'association (voir adresse ci-dessus). - Canadian Acoustical Association/Association Canadienne d'Acoustiquec/o JASCO Applied Sciences2305–4464 Markham StreetVictoria, BC V8Z 7X8 Canada - - - secretary@caa-aca.ca - Dr. Roberto Racca

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President's Message
Message du président

One year already...

This December issue gives us an opportunity to review the many accomplishments that took place over the past 12 months, that are also my first 12 months as President of the Canadian Acoustical Association.

With the support of our dedicated webmaster, Philipp Tsui (Wakefield Acoustics), a good cleanup has been made to our website and this latter was made compatible with the mobile browsers that we so often use. With the additional help from Eugène Popovici, we included dynamic content and the list of our Sustaining Members is always up-to-date and accurate. Also thanks to the dedication of our Executive Secretary, Roberto Racca, who does great work at serving our Sustaining Members who are so vital to our association.

On that note, I would like to thank, in my name and in the name of our association, several of the companies that are generously contributing the time of their employees. Recently, HGC Engineering has authorized Bernard Feder, our Advertisement Coordinator, to spend more time on our association. Here is a nice way to give it back to our Canadian acoustical community and we thank them for that.

Our little community had the opportunity to gather recently during the Acoustics Week in Canada 2018 conference that was held jointly with the 176th Meeting of the Acoustical Society of America, 5-9 November 2018 in Victoria (BC). Thanks to the energy and professionalism of our conference chair, Roberto Racca, and the collaboration of our ex-ex-ex-President, Stan Dosso, this conference had a record number of attendees!

The next edition of Acoustical Week in Canada will be held October 9-11 (week before Thanksgiving) at the Sutton Place in Edmonton (AB). We are delighted to be able to rely on Benjamin Tucker, professor at University of Alberta, to organize our annual congress in a location where we have not been in years.

Finally, let me take this opportunity, before you start reading this issue, to please make sure your contact information is up-to-date, as listed in the membership directory of our 261 subscribers, starting on page 92.

Un an déjà...

Ce numéro de décembre nous permet, comme chaque année de faire un petit bilan des nombreuses réalisations des 12 derniers mois, qui sont également mes 12 premiers à titre de Président de l'Association canadienne d'acoustique.

Ainsi, avec l'appui du notre dévoué webmestre, Philip Tsui (Wakefield Acoustics), un bon petit ménage a été fait de notre site web et ce dernier est maintenant compatible avec les navigateurs mobiles que nous utilisons si souvent. Par ailleurs, avec l'aide supplémentaire de Eugène Popovici, nous avons intégré un affichage dynamique de contenu et la liste de nos abonnés de soutien est ainsi toujours à jour et complète, notamment grâce aux bons soins de notre secrétaire administratif, Roberto Racca, qui fait un travail remarquable pour servir aux mieux nos abonnés de soutien, si important pour notre association.

À ce sujet, je tiens à rendre ici à remercier, en mon nom et celui de notre association plusieurs des compagnies qui nous font généreusement cadeau à notre association de temps de leurs employés. Ainsi récemment, la compagnie HGC Engineering a accepté que notre coordinateur de publicité, Bernard Feder, puisse consacrer un peu plus de temps pour notre association. Voilà une belle façon de redonner à la communauté acoustique canadienne et nous les en remercions chaleureusement.

Notre petite communauté a eu l'occasion de se rencontrer récemment, lors de la Semaine canadienne de l'acoustique 2018 qui s'est tenue conjointement avec le 176e congrès de l'Acoustical Society of America du 5 au 9 novembre 2018 à Victoria (BC). Grâce à l'énergie et au professionnalisme de notre coordinateur de conférence, Roberto Racca et la collaboration de notre ex-ex-ex-président, Stan Dosso, cette conférence aura vu un nombre record de participants!

La prochaine conférence de la Semaine canadienne d'acoustique aura lieu du 9 au 11 octobre 2019 au Sutton Place à Edmonton (AB). Nous sommes très heureux de pouvoir compter sur Benjamin Tucker, professeur à University of Alberta, pour l'organisation de notre conférence annuelle à un endroit où nous n'étions pas retournés depuis des années.

This year again, we marked the missing information with a question mark “?” to make any missing information clear to everyone. Given that we don't have Santa's capabilities, we really need your postal address to send you your journal.

With this customary call for action done, I wish you all season's greetings and happy holidays.

Jérémie Voix
President

Finalement, je profite donc de la tribune qui m'est offerte, pour vous rappeler, avant de commencer la lecture de ce numéro, de bien vouloir vérifier que vos coordonnées, listées dans l'annuaire des 261 abonnés, à partir de la page 92, soient bien à jour. Cette année encore nous avons marqué les champs manquants à l'aide d'un « ? » pour que l'information manquante soit clairement visible pour tous. N'étant pas le père Noël, lorsque nous n'avons pas votre adresse postale, nous ne pouvons pas vous faire parvenir votre journal!

Sur cet habituel appel à l'action, je vous souhaite à tous un très joyeux temps des fêtes.

Jérémie Voix
Président

Case Study: Retrofitted Solution to Address Sound Flanking via Window Mullions of Stacked Residences

Pier-Gui Lalonde[*1]
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1 Introduction

The subject of this case study is a sound transmission issue between stacked residences in a condominium building. The occupants of a third floor suite reported that airborne sounds originating in the suite directly above were clearly audible and disturbing within some of the rooms in their suite. The offending sounds included conversations, television loudspeakers, and the operation of window blinds. The façade of the building featured continuous window mullions of aluminium construction with hollow cores, spanning from windows on the third floor to those on the fourth. These were identified as the probable cause of the noise issue. Without consulting an acoustical engineer, the developers attempted to block a small portion of the inside of some of the mullions with a low-density spray foam product. The third floor occupants reported that this resulted in no audible improvement.

This paper will outline the approach taken to assess the sound transmission issue, and to develop mitigation that was both practical to implement and effective in improving sound transmission loss between the suites.

2 Initial Assessment

An objective evaluation was required to assess the extent and nature of noise transmission between the suites. Integral DX Engineering completed airborne noise isolation testing [1] between two pairs of rooms in each of the identified suites, with the noise sources located in the lower suite. Subjective observations confirmed that most of the test noise in the receiver rooms was emanating from window components. The resulting Noise Isolation Class (NIC) [1, 2] ratings were 53 and 54, which was well below expectations given the separating construction: concrete slab 225 mm thick, with floating hardwood floors above. The one-third-octave band Noise Reduction (NR) results showed that the NIC scores were limited by the performance in the 800 Hz and 1000 Hz bands. Based on a review of test data collected for similar floor-ceiling constructions elsewhere, the NR performance in those bands was approximately 20 dB below expectations.

Therefore, the initial assessment confirmed that the window mullions created significant sound flanking paths, bypassing the direct path through the floor-ceiling. While the overall sound isolation performance still complied with Ontario Building Code requirements between adjacent suites [3, Section 90.11.], the performance was far below the standard set for the project and which could reasonably be expected by purchasers.

3 Evaluation of Noise Mitigation Options

Two primary sound transmission paths via the window mullions were identified: (1) airborne sound transmission via the hollow cores, and (2) vibration transmission along the aluminium walls, re-radiating as structure-borne sound. The relative contribution of each sound transmission path was unknown. However, both paths were considered when evaluating potential noise mitigation options. There were also practical limitations to consider for any proposed solution. Solutions which involved breaking the vibration transmission path were ruled-out, as this would involve significant construction, cost, changes to the building envelope, and changes to the look of the new building.

It is common to fill hollow window mullions or door frames with a dense material (e.g. sand or grout) to mitigate sound transmission via these components [4, p.196]. This would have provided significant mitigation of the airborne sound transmission path, as well as damping of vibrations along the aluminium walls. The application of closed-cell spray insulation to block the mullion cavities at the level of the slab was also considered. Ultimately, there were several concerns with any proposal to introduce material inside the window mullions. Holes would have had to have been drilled to access the cavities. The heat transfer characteristics of the mullions, which form part of the buiding envelope, would have changed, and there were concerns that this would increase the risk of condensation and mould growth. These concerns were compounded by the fact that a central humidifier was planned for the make up air system for the building. Finally, the mullions may not have been adequately blocked to hold aggregate materials in place.

It was proposed to instead investigate mitigation that could be applied to the suite-facing surfaces of the mullions. In addition to improving sound transmission loss, the solution would ideally need to be fully reversible. While applying treatment to mullions on both the third and fourth floors would have been preferable to maximize the potential improvement, all work needed to be done in the third-floor suite only. The appearance of the treated mullions from within the third floor suite was also a concern.

4 Validation of Noise Mitigation

Validation testing was completed in order to gauge the effect of applying a mass-loaded barrier to the surfaces of the window mullions. A 3 m long section of comparable window mullion was used for this purpose, placed horizontally on supports. Initial measurements were completed by tapping one of the suite-facing surfaces of the mullion with a wood dowel, and measuring the vibration acceleration response

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on the same surface at multiple points away from the stimulus. This testing confirmed that vibration transmission was efficient along the length of the un-treated mullion, with no change in the acceleration response at various distances away from the stimulus.

Next, the testing was repeated with approximately half the length of the mullion filled with densely-packed mineral fibre insulation. The acceleration response was reduced by approximately a factor of 2, with the stimulus and measurement near the opposing ends of the mullion.

Finally, the insulation was removed, and tests were completed with one and two of the mullion surfaces covered with a barium-loaded vinyl product, which had been selected for a high surface weight (2.0 lb/ft^2, or approximately 9.8 kg/m^2). The stimulus and measurements were both located on surfaces without the mass-loaded barrier treatment. The acceleration response was reduced by approximately a factor of 2 with two of the three suite-facing surfaces treated, compared to the un-treated condition.

Figure 1: Validation testing setup, with mass-loaded barrier applied to one of the window mullion surfaces.

The testing results showed measurable but modest reductions of vibration transmission by adding mass-loaded barriers under the test conditions. Various adhesives were also tested for their suitability to hold the mass-loaded barrier in place and ease of removal.

5 Final Noise Mitigation Design

The final noise mitigation plan was to affix a mass-loaded barrier to each of the three suite-facing surfaces of each vertical window mullion within the third floor suite. The mass-loaded barriers would then be covered with custom-fabricated aluminium caps, colour-matched to the window frames. To ensure a more consistent look, some horizontal window mullions also received the same treatment. Compared to the validation testing, the mass-loaded barriers would cover a shorter span, but each of the three suite-facing surfaces would receive the treatment (compared to only two of three for the testing). The aluminium caps would provide additional mass, which could only further reduce airborne and struture-borne sound transfer.

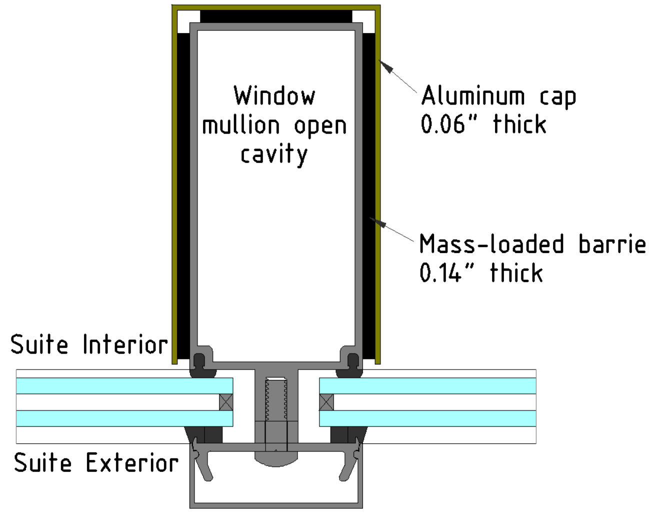

Figure 2: Cross-section of window mullion with acoustic treatment.

6 Implementation and Results

The mass-loaded barriers and aluminium caps were carefully prepared and installed within the third floor suite. The occupants confirmed that, subjectively, the installed noise mitigation had significantly reduced the audibility of airborne sounds from the fourth floor unit, and they were quite pleased with this result. As such, there was no clear value-added in completing any follow-up testing. However, there are other vertically-adjacent suites in the building with the same condition, and so there was a reasonable possibility that implementation of this solution would be desired elsewhere in the future. It was recommended to the Condominium Corporation that, should this be the case, objective testing of the installed mitigation should be done first.

Acknowledgments

The author would like to recognize the contributions of Gregory Clunis to the success of the project.

References

[1] ASTM E336-17a, Standard Test Method for Measurement of Airborne Sound Attenuation between Rooms in Buildings, ASTM International, West Conshohocken, PA, USA, 2017.

[2] ASTM E413-16, Classification for Rating Sound Insulation, ASTM International, West Conshohocken, PA, USA, 2016.

[3] Ontario Ministry of Municipal Affairs and Housing. Ontario Building Code 2012.

[4] M. David Egan. *Architectural Acoustics*. J. Ross Publishing, Inc., 5765 N. Andrews Way, Fort Lauderdale, FL 33309, 2007.

EVALUATING ACOUSTICAL PERFORMANCE OF EXISTING OFFICES AS PART OF A WELL FEASIBILITY SERVICE

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1 Introduction

While the WELL building standard is typically applied during the design of new offices, it can also be applied retroactively to existing offices. Before undertaking such an endeavour, companies may be interested in evaluating their office's acoustical performance with respect to the standard. This paper describes how a WELL feasibility assessment can be performed for the acoustically-focused WELL features. This allows companies to know where they stand with respect to the WELL building standard and what it might take to achieve the different levels of certification.

1.1 Versions of the WELL standard

The WELL standard is currently at v2.0, which brought many changes from v1.0 upon which this feasibility service was initially based. The content has been updates considering these changes. Note that v2.0 is currently in Beta testing; project team can choose to pursue certification under v1.0 or v2.0; and may apply to use v2.0 features for projects registered under v1.0.

In the new version, all acoustically-focused "Features" have been moved into a separate "Sound" category with aspects related to background noise levels, sound isolation, privacy, speech intelligibility and room acoustics. Each of these will be discussed with respect to determining feasibility.

1.3 Feasibility assessment approach

The approach for the feasibility assessment is to minimize disruption to an occupied office and the amount of effort required on-site. Therefore, many aspects of the assessment are based on pre-site visit drawing reviews followed by visual inspections on site. Measurements are limited to background sound levels and balloon-pop reverberation time measurements since these are relatively unobtrusive compared to sound isolation measurements.

2 WELL v2.0 acoustical features

The WELL v2.0 Standard has 5 features related to acoustics, which will be discussed with respect to performing a feasibility assessment.

2.1 S01 - Sound mapping

Achieving the "Sound Mapping" feature is critical since it is a Pre-Condition for WELL certification. The purpose of this feature is to provide the basic components of acoustically comfortable and productive workspaces. The requirements of this feature are related to background sound levels from both HVAC and exterior noise sources, acoustical privacy, and adequate separation of loud and quiet areas.

In assessing background sound, it is simple to perform a few spot check measurements in an occupied office to get a general sense of HVAC noise levels and exterior noise intrusion such as from road and rail traffic. While with v1.0 of the standard, these had to be measured separately, with v2.0 they are now combined into a single assessment. It is therefore possible to measure both exterior noise and interior HVAC noise simultaneously. That said, one source of noise that should not be included is that of people talking. For a quiet office, this may not be much of an issue but for an office with a lot of chatter this could require early morning or evening measurements. A good approach is to take several spot checks at various locations around the office noting the dominant noise source during each measurement. This will allow for efficient data screening.

While this feature does have requirements related to sound isolation and acoustical privacy, there are no specific targets. All that seems to be required is to document expected or measured sound isolation performance.

In the final part of the Sound Mapping feature, it is required to produce a drawing with acoustic zones labelled. Presumably the intention is to show that space planning considered acoustics before the office was built, but for an existing office it may still be useful to apply Loud, Quiet, and Mixed labels to different zones to influence employee behaviors.

2.2 S02 - Maximum noise levels

This feature contains one part called "Limited Background Noise Levels" with suggested dBA and dBC targets based on the both L_{eq} and L_{Max} metrics. Since this is an Optimization, points are awarded for achieving different target ranges. Since the targets are based on different weightings and metrics, it's useful to have a Sound Level Meter (SLM) that can measure everything simultaneously. Combined with a SLM capable of statistics and/or logging, this allows measurements to be performed while walking through an office.

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2.3 S03 - Sound barriers

A more difficult aspect to assess quantitatively in an occupied office is sound isolation and privacy. However, since this is an Optimization, it is not required, but points are awarded for achieving different target ranges.

Part 1 of the “Sound Barriers” feature requires minimum Speech Privacy Potential (SPP) targets to be achieved for different room types. While a drawing review can give a general sense of a walls expected sound isolation performance, this does not factor in construction quality. Qualitatively during a site visit it is possible to visually inspect for sound isolation issues such as walls that do not extend above ceiling tiles, gaps where partitions meet, unsealed doors, etc. It is also possible to listen for sound isolation issues. For example, if someone is talking outside a room and you can clearly hear them. While not as conclusive as a quantitative assessment, apparent sound isolation issues can be flagged as potentially problematic. Based on estimates of sound isolation performance and measured background sound levels, the SPP can be determined for comparison against the target ranges.

Part 2 of this feature is related to the sound isolation performance of entrance doors. Since this part does not require measurements, qualification can easily be determined by inspecting the doors seals and construction.

2.4 S04 - Sound Absorption

Sound absorption is related to speech intelligibility, privacy and noise build-up due to reverberation. Since this is an Optimization, it is not required, but points are awarded for achieving different target ranges.

Part 1 of the “Sound Absorption” feature requires maximum Reverberation Time (RT) targets to be achieved for different room types. These can be measured relatively quickly on site using a balloon pop test, or estimated based on RT spreadsheet models. These should give a general sense of whether the office qualifies for the available point.

Part 2 and 3 are related to the acoustical ceiling tile and acoustical wall treatments for certain rooms, which can easily be determined from percentage area estimates and review of product specifications.

2.5 S05 - Sound Masking

Sound masking is related to privacy and helps minimize distractions. Since this is an Optimization, it is not required, but points are awarded if a sound masking system is installed and operates in the target sound level ranges.

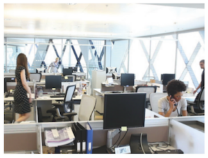
Whether an office meets the requirements of this feature can easily be determined by visual inspection of the ceiling or ceiling plenum accompanied by spot-check sound level measurements.

3 Conclusion

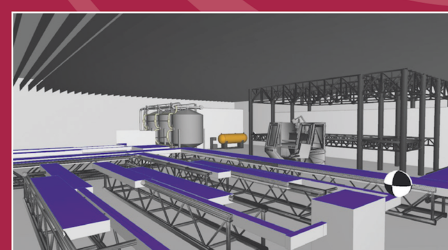
Based on a combination of visual inspections and spot-check sound level measurements, it is possible assess the feasibility of compliance for an existing office with the acoustical features of the WELL building standard. While “Sound” is just one category of the WELL standard, it is also possible to assess compliance with the other aspects of the standard through visual inspects, spot-check measurements, and unattended monitoring. Thus, a full assessment with respect to the WELL Standard can be performed for clients interested in having their offices evaluated.

Acknowledgments

The authors would like to thank Sandra Dedesko and Mike Williams from RWDI and Michelle Xuereb and Vera Gisarov from Quadrangle Architects for their help in developing this feasibility assessment.







DESIGN AND EVALUATION OF A HIGH-SPEED AEROACOUSTIC WIND TUNNEL

Frank Giardino[*1] **and Joana Rocha**[†1]
[1]Department of Mechanical and Aerospace Engineering, Carleton University, Ottawa, Canada, K1S 5B6

1 Introduction

During cruise flight, the main source of acoustic noise radiation within the aircraft cabin occurs as a result of structural vibrations of the flexible fuselage panels due to the random pressure fluctuation field imposed by the Turbulent Boundary Layer (TBL) [1]. Conventional methods of describing these interactions have relied on the use of various statistical semi-empirical models which predict the behavior of the TBL pressure fluctuation spectrum. Each model however makes fairly different predictions with regards to the spectrum in the various frequency regions. There is therefore a need to not only assess these inconsistencies with experimental methods, but also to clarify the fundamental physical relationship between the turbulent structures and the resulting fluctuation signature. The present phase of this research initiative at Carleton University involves the design and fabrication of the new High-Speed Aeroacoustic Wind Tunnel (HSAWT), which is capable of studying wall pressure fluctuation behavior at subsonic flow speeds up to typical cruise flight conditions.

2 Wind Tunnel Design

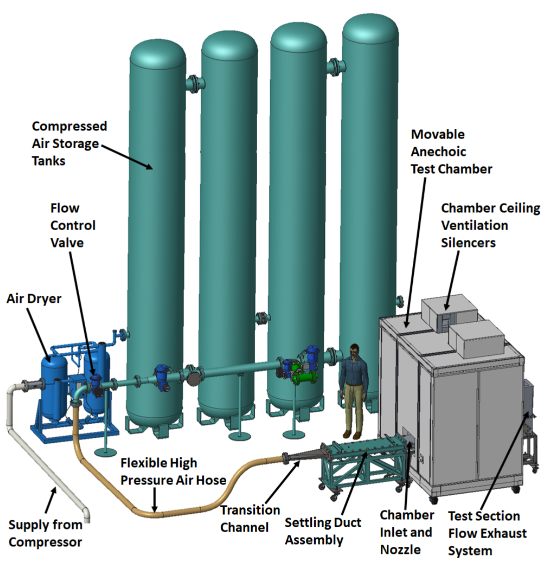


Figure 1: Carleton HSAWT facility.

The complete HSAWT facility is displayed in Fig.1, which makes use of a fully anechoic chamber to house an open jet test section. The wind tunnel is a blowdown type facility which operates using large compressed air reservoir tanks. Flow through the wind tunnel is achieved by discharging the air in the tanks in a controlled manner through a control valve. Constant test section flow conditions are achieved using a feedback control system which utilizes measurements of total and static pressure inside the test section to control the Mach number. Flow through the control valve is delivered to the chamber through a set of upstream components and flow straightening devices which are designed to properly guide and condition the flow. The flow is then accelerated into the test section to the required speeds using a nozzle assembly which is fed into the chamber and houses a 2D planar contraction profile. The chamber is built with acoustic paneled walls and is internally lined with anechoic wedges, providing the chamber with a cut-off frequency of 250 Hz. Two ventilation holes on the chamber ceiling, which are fitted with acoustic silencers, allow for pressure equalization within the chamber at high speeds. The test section houses a test panel with an array of holes to flush mount pressure fluctuation sensors within the potential core of the jet. Flow over the panel is evacuated out of the chamber using a specially designed exhaust system. This system first contains a test section jet collector to properly capture the flow. The flow is then exhausted out of the chamber vertically through a set of diffuser duct components, as well as a 90°corner fitted with turning vanes. The walls of the exhaust system are also acoustically treated to help suppress noise transmission back into the chamber.

3 Wind Tunnel Characterization

3.1 Flow Control Response

The flow control system was evaluated to determine the amount of steady run time available before the reservoir pressure is depleted. The freestream Mach number from the nozzle was computed along the centerline axis using pressure measurements from a suspended pitot-static probe. The results from this study indicate that the target Mach number is achieved within a settling time of roughly 12-15 seconds for all flow speeds. Constant control of the Mach number for at least 30 seconds is also reasonably achieved in the range from Mach 0.1 to 0.7. As the speed is increased to the maximum limit of Mach 0.8 however, the control system response is less steady, where the control valve seems to have a difficult time in compensating for the drop in tank pressure at a flow rate of approximately 3 kg/s. It is envisioned that future work in control system parameter optimization, combined with slight set-up modifications to lower the required mass flow rate, will provide improved control at higher speeds.

3.2 Background Noise Levels

Background noise levels within the test chamber were characterized to ensure that the expected magnitudes of the measured pressure fluctuation spectra are sufficiently large to

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avoid any signal contamination. Free-field chamber noise measurements were conducted using a Bruel and Kjaer 4944-A 1/4" microphone, with the sensor placed perpendicular to the nozzle orifice at a horizontal distance of 1.2 m. The results of this study confirmed that the chamber achieves an acceptable signal-to-noise ratio of at least 10 dB for almost all test conditions. Issues of signal noise contamination however may be possible at flow speeds around Mach 0.1 due to low levels of expected TBL surface pressure fluctuation energy. For this reason, alternative signal processing methods were implemented to ensure that noise contamination is minimized at all test section speeds.

4 Surface Pressure Fluctuation Measurements

Measurements of the surface pressure fluctuation spectrum were conducted using flush mounted microphones with a 5 mm pinhole cap above the sensor diaphragm for increased spatial and temporal resolution. A single sensor was used to measure the fluctuations at the point of interest while a secondary sensor was used as a reference signal in a noise cancellation technique. Fig.2 contains results of the measured spectrum for the entire range of governable test section Mach numbers. The magnitude of the spectrum is represented on the decibel scale relative to 20 μPa.

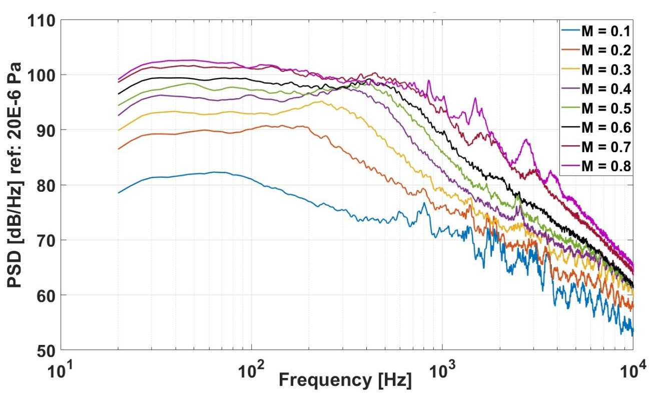

Figure 2: Comparison of measured surface pressure fluctuation spectra for various test section flow speeds.

The measured spectral behavior displays the expected trend of increasing power for higher flow speeds at all frequencies. The peaks of the spectra occur around 350 Hz and exhibit a main high frequency attenuation region of relatively constant slope. The spectra between Mach 0.2-0.6 also exhibit similar spectral peak and roll-off behavior as described by Rackl et al. [2] in their flight test measurements (slight "hump" in spectral peak before attenuation). In general, the spectra seem to display a lack of energy in the overlap/high frequency regions with a low spectral peak roll-off as the speed is increased to Mach numbers above 0.6.

In addition to the stand-alone measurements presented, the spectra were also compared with established spectrum models in literature as summarized by [1, 2]. Fig.3 contain plots of the data comparisons with the model predictions at both the low and high test section velocity limits.

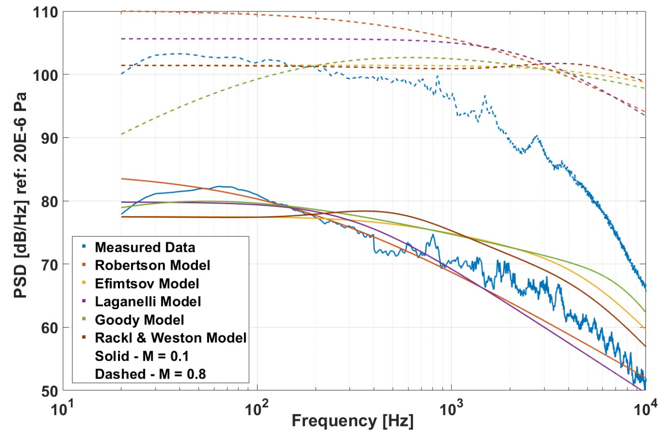

Figure 3: Comparison of measured surface pressure fluctuation spectra with predictions from literature models.

In general, the low speed data displays agreement with Robertson's model within the low frequency range, as well as a similar high frequency attenuation slope. For higher Mach numbers, the models predict a large energy shift in the spectrum to higher frequencies, thus the spectra seem to shift towards slightly lower energy levels predicted by Efimstov and Rackl & Weston within the low frequency region. The high frequency regions however are still underrepresented in the data. This discrepancy in quick attenuation could be attributed to the sensor configuration utilized, underdeveloped TBL in the test section, and/or over estimated high frequency energy levels by the models for thinner TBL conditions.

5 Conclusions

The HSAWT facility commissioning and results of the initial pressure fluctuation studies conducted provides the necessary ground work for future research and improvements. The wind tunnel was able to obtain governed test section flow speeds up to those experienced in cruise flight with adequate low background noise levels. The implementation of the HSAWT seeks to provide an aeroacoustic test facility that is unique among many around the world, with the ultimate goal of mitigating the need for expensive flight tests to research TBL pressure fluctuations and their impact on the design of fuselage panels for the reduction of cabin noise generation.

Acknowledgments

The work presented was performed with the generous financial support from the Consortium for Research and Innovation in Aerospace in Quebec (CRIAQ) and the National Sciences and Engineering Research Council (NSERC).

References

[1] T.S. Miller, J.M. Gallman, and M.J. Moeller. Review of turbulent boundary-layer models for acoustic analysis. *Journal of Aircraft*, 49:1739–1754, 2012.

[2] R. Rackl and A. Weston. Modeling of turbulent boundary layer surface pressure fluctuation auto and cross spectra - verification and adjustments based on tu-144ll data. *NASA Langley Research Center*, Contractor Report CR-2005-213938:1–88, 2005.

Inciting Our Children To Turn Their Music Down: The AYE Concept Proposal

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1 Introduction

According to the World Health Organization (WHO), more than 1.1 billion people are currently at risk of losing their hearing due to excessive exposure to noise. Of this, a significant proportion consists of children, youth and young adults who are exposing themselves to excessive levels of sound through various leisure activities (music players, concerts, movies at the theatre, dance clubs, etc.).

To address this issue, many approaches have been developed, ranging from general awareness messages to volume limiters on personal music players. For instance, the recent "Make listening safe" [1] initiative from WHO aims at gathering all stakeholders, public health authorities, and manufacturers to define and develop a consolidated approach to limit these non-occupational sound exposures, based on dosimetry. Indeed, significant efforts have been put into the idea of assessing directly on a PMP (personal music player) the individual noise dose, i.e. the product of the level (L_{eq}) and the duration, induced during music listening.

While many technical issues are still actively discussed in some related standards like the recently released [2] or the under development within ITU Q28/16 on Safe Listening (F.SLD), a major concern arose with regards to the message communicated to the end-users. End-users need to be educated on the risk of noise induced hearing loss (NIHL) and its irreversibilily, but at the same time they also need to be made aware that NIHL is 100% preventable pending safe listening practices are followed.

More importantly, end users have to be left with an appealing noise dose measurement. In that regard, expressing equivalent sound pressure level in decibels (dB) or the noise dose in percentage (%) is of little value given the complexity of one and the abstraction of the other. But communicating about the dangers of music playback is definitely something very new for most of the hearing conservation specialists and communicating with this particular group of youth is only adding to the difficulty.

In the quest for a meaningful message to pass to these young end users, this article introduces a new metric, the "Age of Your Ears" (AYE), that is an indication of the predicted extra aging caused by the excessive noise dose each user is exposed to. To perform such prediction, a multiregression statistical model was developed based on normative data found in ISO 1999 [3] standard. This way, an AYE value can be computed for each subject, using only his age, sex and sound exposure, to represent the possible acceleration of aging caused by excessive music listening.

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2 Method: Computation of AYE

The AYE is equivalent to an age penalty, A, added to the real age Y, and computed so that the median value of hearing threshold, denoted $H_{0,50}$, of otologically normal person of the same sex is equal to the noise-induced permanent threshold shift $N_{0,50}$, depending on the $L_{EX,8h}$ measured for that person.

The median value of hearing threshold of otologically normal person of the same sex, $H_{0,50}$, is given in Annex A.1 of ISO 1999 as follows:

$$H_{0,50} = a(Y-18)^2 + H_{0,50;18} \tag{1}$$

Where $H_{0,50;18}$ is the median value of hearing threshold, $H_{0,50}$, at age 18 and a is a coefficient depending on the frequency and the user's sex. It is assumed to be zero for practical purposes, as specified in ISO 7029 [4].

The noise-induced permanent threshold shift $N_{0,50}$ is defined in section 5.3.1 of ISO 1999 and given by:

$$N_{0,50} = \left[u + v * \log_{10}\left(\frac{Y-Y_0}{\theta_0}\right)\right](L_{EX,8h} - L_0)^2 \tag{2}$$

Where Y is the current age and Y_0 is the subject's age when the exposure began, both expressed in years. L_0 is the cut-off sound pressure level in decibels defined in Table 2 of ISO 1999 and u and v are frequency dependent parameters provided in Table 1 of ISO 1999. Finally, θ_0 is set to be 1 year in ISO 1999. This expression applies if $(L_{EX,8h} - L_0) > 0$ and $(Y - Y_0) > 10$. Otherwise, if $(L_{EX,8h} - L_0) > 0$ and $(Y - Y_0) < 10$:

$$N_{0,50} = \frac{\log_{10}((Y-Y_0)+1)}{\log_{10}(11)} \, N_{0,50}|_{Y-Y_0=10} \tag{3}$$

Finally, if both $(L_{EX,8h} - L_0) < 0$ and $(Y - Y_0) < 10$ then

$$N_{0,50} = 0 \tag{4}$$

After adding the age penalty A to the age Y in Eq.1, making $H_{0,50}$ and $N_{0,50}$ equals leads to the following three possible equations:

$(Y + A - 18)^2 =$

$$\begin{cases} \dfrac{[u + v \log_{10}(Y - Y_0)]}{a} (L_{EX,8h} - L_0)^2 \\ \qquad \text{if } (L_{EX,8h} - L_0) > 0 \text{ and } (Y - Y_0) > 10 \quad (5) \\ \dfrac{\log_{10}((Y - Y_0) + 1)}{a \cdot \log_{10}(11)} N_{0,50}|_{Y - Y_0 = 10} \\ \qquad \text{if } (L_{EX,8h} - L_0) > 0 \text{ and } (Y - Y_0) < 10 \quad (6) \\ 0 \\ \qquad \text{if } (L_{EX,8h} - L_0) < 0 \text{ and } (Y - Y_0) < 10 \quad (7) \end{cases}$$

Eq. 5, 6, and 7, can be solved to compute the age penalty A. Two root values can be expected because of the square in the left member. In the end, only the positive values are kept and added to the real age Y because, unfortunately, listening to music cannot make your ears younger.

3 Results: Accelerated Aging Curves

From Eq. 5, 6, and 7, a set of curves can be obtained, for any given age that predicts the AYE as a function of the sex, the exposure duration, the L_{eq} and the frequency of the sound. For example, Fig. 1 shows the AYE of a person exposed since the age of $Y_0 = 25$. The curves are a function of the current age Y and the graph shows the AYE for different levels.

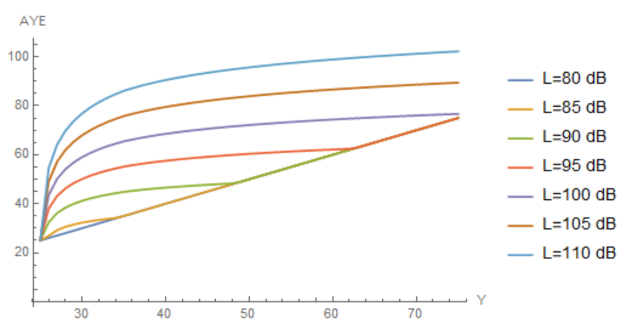

Figure 1: Calculation of AYE as a function of the age, for a male subject exposed since age $Y_0 = 25$. These curves show clearly the accelerated apparent aging of the ear for a critical frequency band of 3 kHz.

The graph shows, for example, that if a man listens to a sound at 90 dB for 8 h daily since he's 25, the age of his ears will be 40 the moment he turns 30, for the most critical frequencies, the 3 kHz octave band. The visible break in every curve shows the moment when noise induced hearing loss becomes negligible compared to aging.

Form another perspective, the graph in Fig. 2 shows the evolution of the AYE as a function of the level of exposure, with the same parameters. This time, the final age is what changes from one curve to another.

4 Conclusions

In a world where personal musical players are ubiquitous, and have also been putting hearing at risk, it is interesting to see them as potential tool, not only to address the issues they created, but also for raising awareness on the dangers of Noise-Induced Hearing Loss at large.

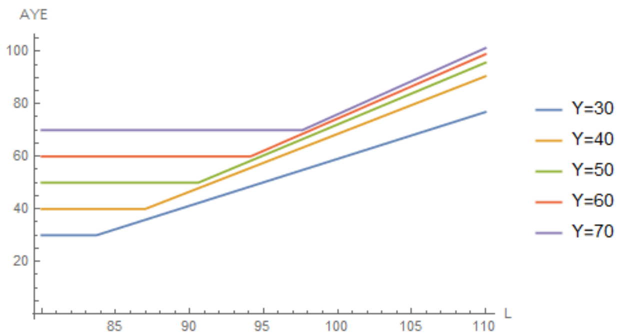

Figure 2: Calculation of AYE as a function of the level of exposure, for a male subject exposed since age $Y_0 = 25$. Those curves show clearly the influence of the level of exposure on the apparent aging of the ear, again for a critical frequency band of 3 kHz.

The proposed AYE metric will be first implemented in a measurement manikin setup that is currently under development at the Centre for Interdisciplinary Research in Music Media and Technology, housed at the Schulich School of Music at McGill University (CIRMMT). This setup, further described in [5], is inspired by the "Jolene" manikin developed though the "Dangerous Decibels" program [6]. The resulting *measurement kiosk* will be complemented by a smartphone-based measurement app that will enable musicians to assess their entire noise exposure. It is hoped that the proposed AYE metric will be relevant and simple enough to have a beneficial impact on everyone's safe hearing practices.

References

[1] WHO | Make Listening Safe - http://www.who.int/deafness/activities/mls/en/.

[2] CENELEC. BS EN 50332-3:2017 - Sound system equipment: headphones and earphones associated with personal music players. Maximum sound pressure level measurement methodology. Measurement method for sound dose management, 2017.

[3] ISO 1999:2013 - Acoustics – Estimation of noise-induced hearing loss, 2013. 00000.

[4] ISO 7029:2017 – Acoustics – Statistical distribution of hearing thresholds related to age and gender, January 2017.

[5] Jérémie Voix, Romain Dumoulin, Julia Levesque, and Guilhem Viallet. Inciting our children to turn their music down : the AYE proposal and implementation. In *Proceedings of Meetings on Acoustics*, volume Paper 3007868, Victoria, BC, Canada, 2018. Acoustical Society of America.

[6] Dangerous Decibels - JOLENE - http://dangerousdecibels.org/jolene/.

FURTHER PREDICTION OF HEAVY WEIGHT DROPS ON RESILIENT SPORTS FLOORS IN EXISTING BUILDINGS

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1 Introduction

The issue of heavy weight drops in buildings has been an issue for a number of years [1–6]. Currently, the assessment of the noise and vibration due to heavy weight drops in an existing building can be quite cumbersome. All of the potential floor coverings and the heavy weights need to be shipped to site. Typically, the impact sources used onsite are whatever happens to be present at the site. Overall, this testing regimen is quite arduous, time consuming, and not very repeatable. In recent years, the authors have built a drop tower to repeatedly test fitness flooring performance in a controlled environment [4–6]. This paper looks at ways to predict the in situ performance of fitness flooring by incorporating force pulse data collected from a drop tower and measured transfer functions. This would be a narrow band analysis that can be converted into one-third octave bands as opposed to the one-third octave band analysis that others [7] have suggested. That analysis used a method similar to the Delta IIC in ASTM E2179 [8].

Figure 1: Sudo field testing of fitness tiles

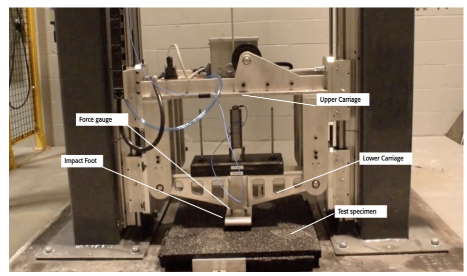

Figure 2: Heavy Weight Drop Tower at rest

2 Experimental Setup

For this experiment, three different performance levels of fitness flooring were used. They are, in increasing performance order, GenieMat FIT08, a 8 mm recycled rebounded rubber sheet, GenieMat FIT30, a 30 mm recycled rebounded rubber tile and GenieMat FIT70, a 70 mm recycled rebounded rubber tile.

The fitness flooring tiles were installed on a second floor composite deck at the Pliteq laboratory in Woodbridge, ON for a sudo-field test. A machined, semi-spherical mass was lifted to an initial height of 0.5m above the fitness floor Fig 1. It was released from rest and allowed to impact once before it was caught. Two accelerometers were placed on the same composite deck as the fitness tiles a few meters away. The vibration at each accelerometer was measured due to drops on each of the different fitness flooring solutions.

The force pulse was measured on the three different fitness flooring with Pliteq's proprietary drop tower Fig 1. Two carriages are supported on low friction rails as to only allow one axis of motion. The upper carriage lifts the lower carriage to a selected height and releases it so that the lower carriage will impact the test specimen with close to free-fall like conditions. The lower carriage can be fitted with various load plates to adjust the mass of the lower carriage and impact foot shape can be changed to simulate different types of weight impacts. A load cell measures the impact force pulse. For this experiment, the weight of the lower carriage was adjusted to match the semi-spherical mass used for the sudo-field test and released from 0.5m

An impact sledge hammer was used to impact the same location as the heavy weight drop on the composite deck. The force impulse and the resulting accelerations were measured. The impact hammer input force and resulting vibration were used to calculate a transfer function. This

transfer function was combined with the force pulse obtained from the drop tower to derive an estimated acceleration that can be compared to the actual measured vibration.

3 Results and Analysis

The measured force pulse on the three types of fitness flooring are shown in Fig 3. These measurements were obtained from the drop tower after improvements were made to reduce high frequency noise compared to what was used previously [6]. As expected, as the fitness flooring increases in performance, the force pulse decreases in amplitude and increases in contact time. The frequency response also changes such that the cutoff frequency of the apparent low pass filter decreases.

These force pulses were combined with the measured transfer function to calculate an estimated time history and frequency response of the resulting vibration due to a heavy

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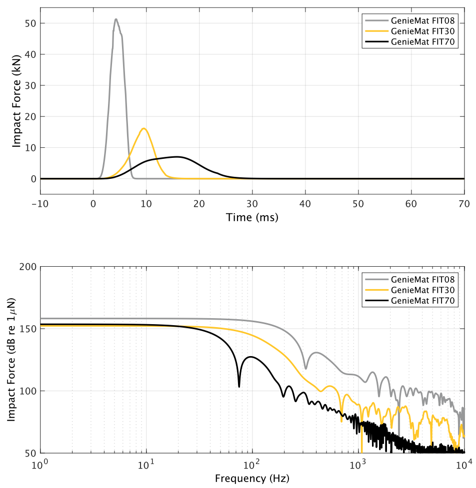

Figure 3: Measured Force Pulse on GenieMat® FIT

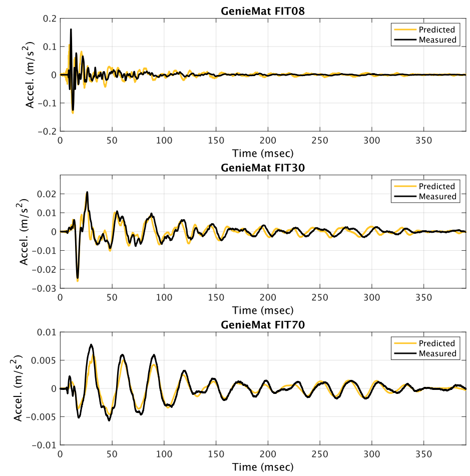

Figure 4: Predicted vs Measured Vibration in Time Domain

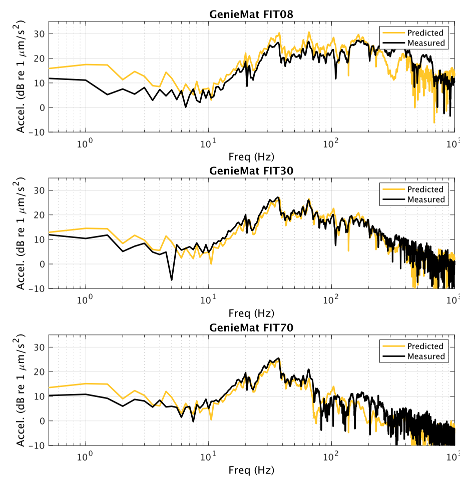

Figure 5: Predicted vs Measured Vibration in Frequency Domain

weight drop. The predicted verse measured time history is shown in Fig 4. The predicted verse measured frequency response is shown in Fig 5.

The three sets of time histories and frequency responses show good agreement. The frequency response estimates for all three fitness floorings show the best agreement with the measured response above 10 Hz. Below 10 Hz, the predicted level is always greater than the measured response, therefore, the estimate can be used as a worse case. The predicted frequency response for impact on GenieMat FIT30 and GenieMat FIT70 is very close above 10 Hz. However, the predicted frequency response for the impact on GenieMat FIT08 is higher then the measured. This may be a result of nonlinear damping in the structure that is present as the amplitude of vibration increases. Further work is warranted.

4 Conclusions

As previously shown, the force pulse of a heavy weight dropped on fitness flooring can be measured in a controlled laboratory environment. A transfer function between the impact force at one location and the acceleration at a second location can be measured. This transfer function can then be combined with the laboratory measured force pulse to obtain an estimated time and frequency response. This calculated estimate shows good agreement with the in situ measured time and frequency response due to a heavy weight impact. Further work is needed to improve the methodology and to extend this methodology over larger distances and building types.

References

[1] Paul Gartenburg and Paul Downey. Comparing various fitness flooring assemblies using heavy/soft and heavy/hard impact. San Francisco, CA, US. Internoise 2015.

[2] Paul Gartenburg and Tony Nash. Fitness noise control products – should we be measuring system or material properties? Providence, RI, US. NoiseCon 2016.

[3] Matthew V. Golden and Paul Gartenburg. The effectiveness of resilient sports flooring on noise from crossfit activities. The Journal of the Acoustical Society of America 139, 2038 (2016); Presentation.

[4] Paul Gartenburg and Matthew V. Golden. Comparing force impulses for various fitness flooring assemblies. Grand Rapids, MI, US. NoiseCon 2017.

[5] Matthew V. Golden. Drop tower testing—the next step in heavy weight impact testing. The Journal of the Acoustical Society of America 143, 1762 (2018); Presentation.

[6] Matthew V. Golden and Paul Gartenburg. Prediction of heavy weight drops on resilient sports floors in existing buildings. Chicago, IL, US. Internoise 2018.

[7] John LoVerde, Rich H. Silva, Wayland Dong, and Samantha Rawlings. Investigation into a standardized test method for measuring and predicting heavy weight impact noise transmission. San Francisco, CA, US. Internoise 2015.

[8] ASTM E2179-03. Standard test method for laboratory measurement of the effectiveness of floor coverings in reducing impact sound transmission through concrete floors. ASTM International, West Conshohocken, PA, 2016, www.astm.org.

EFFECTS OF NOISE EXPOSURE ON HEARING HEALTH EVALUATED THROUGH SHORT INTERVAL OTOACOUSTIC EMISSION MONITORING

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1 Introduction

Current advances in hearing research showed that noise exposures that were thought benign for decades are not without any risks [1]. Moderate levels of noise exposure might not induce hearing threshold changes in quiet conditions in the short term, but damage to inner hair cell's synapses and the auditory nerve fibres might occur. These hidden damages to the ear are usually detectable within a few days and usually impede speech intelligibility in noisy conditions [2, 3]. However with current techniques, effects on humans' synapses and auditory nerve fibres are only detectable once the damage is irreversible. Therefore, the methods to detect the hidden hearing damages do not actually prevent them. Fortunately, changes in otoacoustic emission levels are usually detectable within minutes post-exposure and might give insight on the risk of possible underlying damages and therefore it may be possible to take action before it is too late.

The current study was designed to monitor short-term effects of noise exposure on hearing health through close monitoring of otoacoustic emission levels. The growth function parameters of distortion product otoacoustic emissions (DPOAE) measurements were selected to detect changes that could be related to synaptopathy or other inner-ear pathologies onset in industrial workers.

2 Monitoring otoacoustic emissions growth functions

Growth function DPOAEs can be used to evaluate two characteristics of OHC damage: 1) the decline in absolute DPOAE level and 2) the linearization of the cochlear amplification. However, testing the entire growth function on the whole DPOAE spectrum on workers *in-situ* in a factory would be time consuming and inefficient. Since the cochlear compression in humans occurs mostly around L_2 varying from 50 to 60 dB (SPL) [1], these stimuli levels would be sufficient to observe the onset of changes in cochlear mechanics.

The growth functions were measured with L_2 levels increasing from 50 to 60 dB(SPL) in 5 dB step to monitor outer hair cell activity about every 20 minutes. The measurements were performed on f_2 frequencies from approximately 4.0 to 6.2 kHz in order to save a few minutes, since DPOAE measurements are time sensitive [4] and DPOAE changes due to noise exposure are mostly detected in high frequencies [5]. The absolute DPOAE levels at L_1/L_2 = 65/55 dB(SPL), can be easily extracted from the growth function measurement and compared with other DPOAE measurements over the duration of the noise exposure. As a result, more valuable data is recorded within each measurement.

Participants for the study were selected based on their best ear at the pure-tone audiometry test. Before their work shift, participants were asked to record their DPOAE growth function as a baseline. During their daily noise exposure at work, a timer was set to alarm them every 20 minutes to start a growth function measurement. Unprotected and protected noise exposure levels were respectively recorded continuously with the outer-ear and inner-ear microphones of the hearing protector equipped with electronic components to perform otoacoustic emissions measurements. At the end of their work day, participants recorded a growth function every 3 minutes for 24 minutes.

The low-exposure group consisting in four participants aged between 21 and 31 years old was tested in quiet laboratory conditions at their office desk, with ambient noise levels fluctuating generally between 40 and 65 dB(A). The moderate-exposure group consisting in 3 participants aged between 36 and 44 years old in a CNC machining workshop, was exposed to noise levels fluctuating between 45 and approximately 100 dB(A) at their workplaces.

3 Preliminary experimental results

Results from a typical day of measurements on the moderate-exposition group and low-exposition group is displayed in Fig. 1. Measurements at t_1= 0 minutes, t_2= end of their work shift and at t_3= t_2 + 30 minutes are shown in order to observe the evolution of the DPOAE levels input/output functions. From left to right an increase in the DPOAE levels should occur due to the increase in DPOAE stimuli levels from L_2=50 to 60 dB(SPL). Using the second order polynomial fitting function, the cochlear gain functions can be evaluated for each subjects for the tested frequencies. The second order polynomial function $p(x) = p_1x^2 + p_2x + p_3$ was compared across the various moments in the day (at times t_1, t_2 and t_3) as shown in Fig. 2. The p_1 coefficient represents the compression of the cochlear function and is therefore the most interesting in this study.

4 Discussion

According to the compression curve presented in the litterature [1], more compression is expected in subjects with normal hearing thresholds. The smaller p_1 coefficient magnitude at t_2 in Fig. 2 indicates an increase in amplification, instead of compression. This is shown for f_2 = 4362 Hz with a participant in the moderate-exposure group. This indicates some

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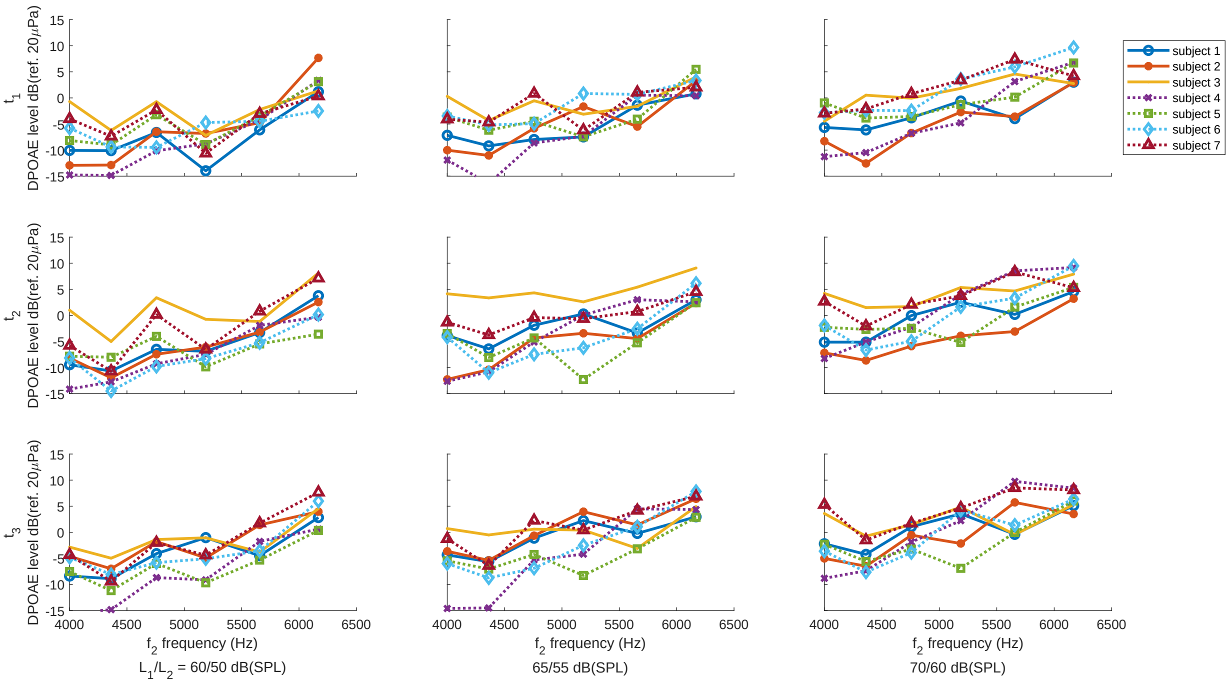

Figure 1: Growth function of DPOAEs for f_2 frequencies from 4000 to 6169 Hz with three participants from the moderate exposure groups (subjects 1 to 3 in solid lines) and four low exposure participants (subjects 4 to 7 in dotted lines) on a typical workday. Otoacoustic emission levels are displayed at t_1= 0 minutes, t_2= end of their work shift, t_3= t_2 + 30 minutes, from top row to bottom row respectively.

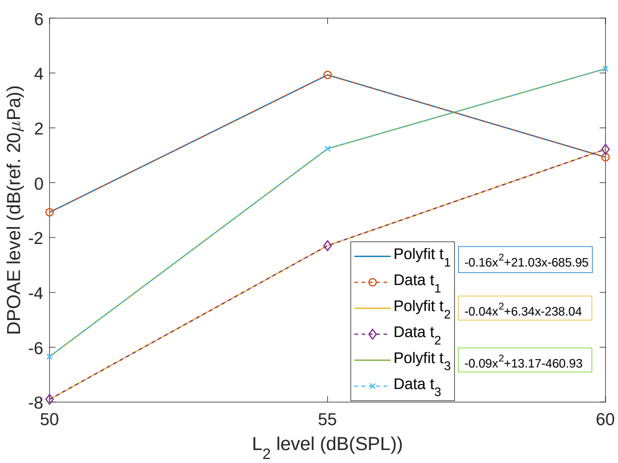

Figure 2: Typical growth functions of DPOAE levels with L_2 levels ranging from 50 to 60 dB(SPL) with a 5 dB step, displayed with their second order polynomial. These functions were measured at t_1, t_2 and t_3 on one measurement day.

effects of the noise exposure on the ear. More measurements throughout the day and over more days need to be analysed in order to get significant conclusions. Furthermore, participants and daily results should be classified by average levels of noise exposure in order to clearly see the differences in compression between conditions and link the changes to the condition. On the other hand, the results show that DPOAE levels are in general consistent with previously found results, and a good indicator of noise exposure.

Acknowledgments

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References

[1] Hari M Bharadwaj, Salwa Masud, Golbarg Mehraei, Sarah Verhulst, and Barbara G Shinn-Cunningham. Individual differences reveal correlates of hidden hearing deficits. *The Journal of Neuroscience*, 35(5):2161–2172, 2015.

[2] Sharon G. Kujawa and M. Charles Liberman. Synaptopathy in the noise-exposed and aging cochlea: Primary neural degeneration in acquired sensorineural hearing loss. *Hearing Research*, 330:191–199, December 2015. 00038.

[3] MC Liberman. Noise-Induced Hearing Loss: Permanent Versus Temporary Threshold Shifts and the Effects of Hair Cell Versus Neuronal Degeneration. In *Advances in Experimental Medicine and Biology*, pages 1–7. Springer New York LLC, 2016.

[4] Miguel Angel Aranda de Toro, Rodrigo Ordoñez, Karen Reuter, Dorte Hammershoi, and others. Recovery of distortion-product otoacoustic emissions after a 2-kHz monaural sound-exposure in humans: Effects on fine structures. *The Journal of the Acoustical Society of America*, 128(6):3568–3576, 2010. 00003.

[5] Stéphane F Maison, Hajime Usubuchi, and M Charles Liberman. Efferent feedback minimizes cochlear neuropathy from moderate noise exposure. *The Journal of Neuroscience*, 33(13):5542–5552, 2013.

AEROACOUSTIC ISSUES OF BUILDING ELEMENTS

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1 Introduction

During high wind events, certain building elements have the potential to generate significant tonal noise that can be heard miles away. These aeroacoustic issues are due to an interaction/coupling between an unstable fluid flow and a feedback mechanism. Aeroacoustic issues are often easy to avoid when susceptible geometry can be identified during the early design process, but mitigation can be technically difficult and very costly once issues do occur. Because aeroacoustic issues are unique and often annoying, they are often considered newsworthy and can be the subject of significant publicity.

2 Aeroacoustic mechanisms

Typically, wind-induced noise from architectural elements arises from one of three main mechanisms: vortex shedding over a bluff body, cavity resonance, or flow through repeated perforations/slotted openings. Although these mechanisms usually occur independently, in specific situations two or even all three of these mechanisms may work in combination.

Each of these three mechanisms are initiated by a flow instability at which alternating flow, or vortices, shed from one side to the other. As the wind speed increases, so too does the rate of the alternating flow. When the frequency of the shedding gets close to the frequency of resonance, they lock together which may result in the generation of significant tonal aeroacoustic noise.

2.1 Vortex shedding

Wind flowing around a bluff body, or a non-streamlined object, such as a cable, railing, beam, plate, panel etc., has potential for tonal noise due to vortex shedding.

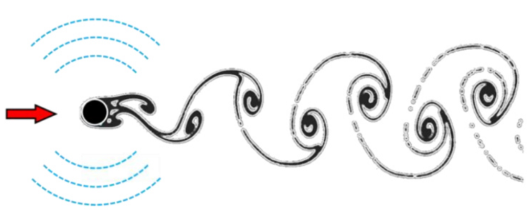

Figure 1: Illustration of vortex shedding off a cylinder.

As the wind alternates, forces are imparted on the structure. This is especially a concern where the vortex shedding frequency matches a structural resonance or acoustic mode. As a result, vibration/noise can then be radiated in one of two ways as illustrated in Figure 2.

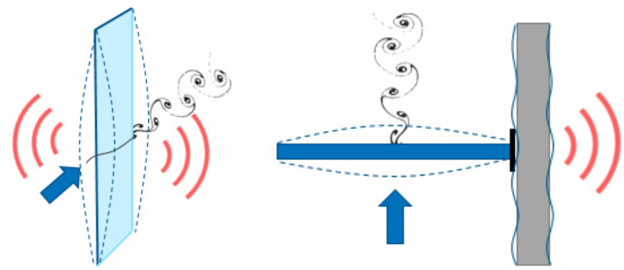

Figure 2: a) Object is large enough to radiate noise as vibration. b) The bluff body transmits vibration to a connected structure, which radiates the noise.

a) If the object is large enough, it may alone radiate vibration due to vortex shedding as noise. This is similar to the way the reed/mouthpiece vibrates and generates noise for a woodwind instrument.
b) The vibration of the bluff body may be transmitted to a connected structure, which in turn, may radiate noise. This is similar to the vibration of the guitar string transmitted to the body of the guitar, which radiates the noise.

2.2 Cavity resonance

Wind flowing across the opening of a slot or cavity can create a strong tone similar to blowing across the pan flute or open bottle. For cavity resonance, the air flow is alternating into and out of confined volume of air, similar to blowing over the top of a bottle. Common cavity geometries encountered on buildings include window mullions, stacking joints, and building maintenance tracks.

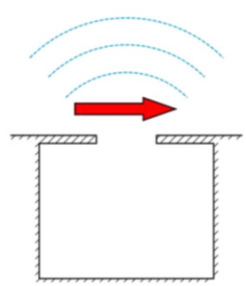

Figure 3: Illustration of flow across a cavity.

2.3 Perforation noise

Wind flowing across or through a repeated perforation pattern can create a reinforced tone-like noise due to the repeated geometry. This may result in an amplification and

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synchronization of a number of separate perforated panels. In these instances, low noise sources (individual holes) may combine to create significant sound pressure levels. Perforated panels are often used as elements of a cladding system, or a part of a sunshade, balcony, or catwalk.

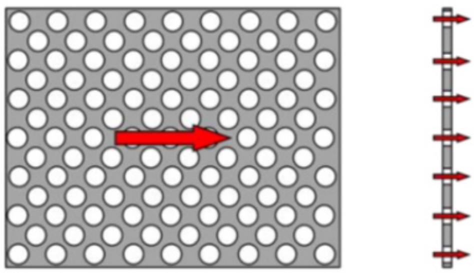


Figure 4: Illustration of flow through and across a perforated plate.

3 Assessment of risk

In order for aeroacoustic noise to be generated, three conditions must be met:

1) The building feature must be capable of one of the three mechanisms,
2) The wind must flow past the feature/geometry with the right direction and speed,
3) The frequencies associated with the interaction must be within the audible range.

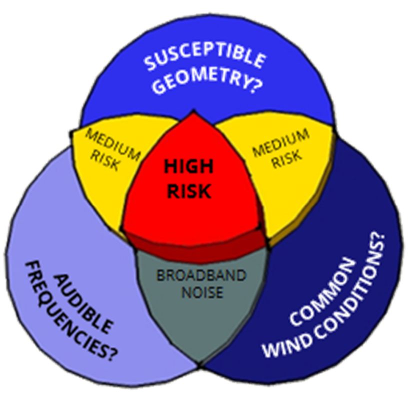


Figure 5: Three required conditions for the generation of aeroacoustic noise.

3.1 Local wind conditions

Wind-induced noise phenomena occur strongest at certain wind speeds and wind flow directions with respect to the architectural feature. Wind speed also varies predictably with height, so these wind speeds can be adjusted to whatever the height of the building or the element is.

Therefore, knowledge of the local wind climate helps to determine the associated risk as we can assess what problems might occur within a reasonable range of common wind speeds. If the right wind conditions are expected for only 1 hour/year, there may not be concern.

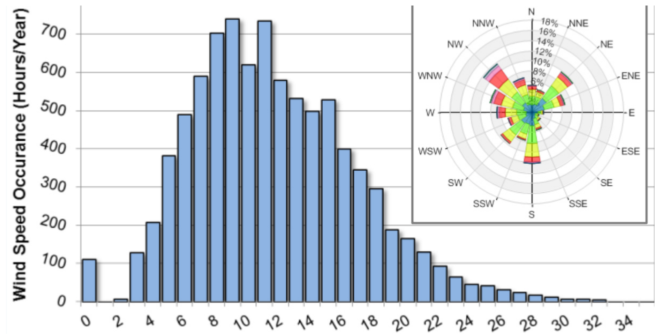


Figure 6: Example of historical wind data (speed and direction) in a specific wind climate.

3.2 Audible frequencies

Pressure oscillations or objects vibrating in moving air can occur at any frequency, but only those in the range of 20 to 20000 Hz are potentially audible. Moreover, people are less sensitive to noise as the frequency nears the upper and lower frequency limits

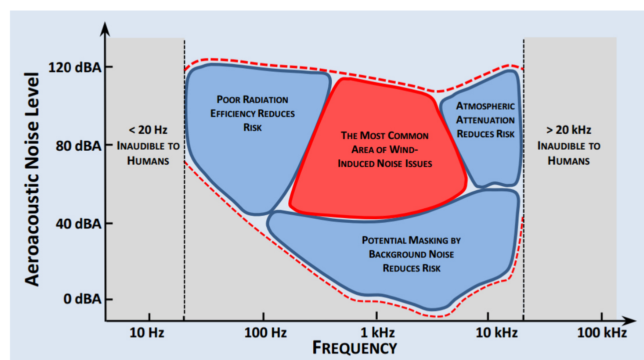
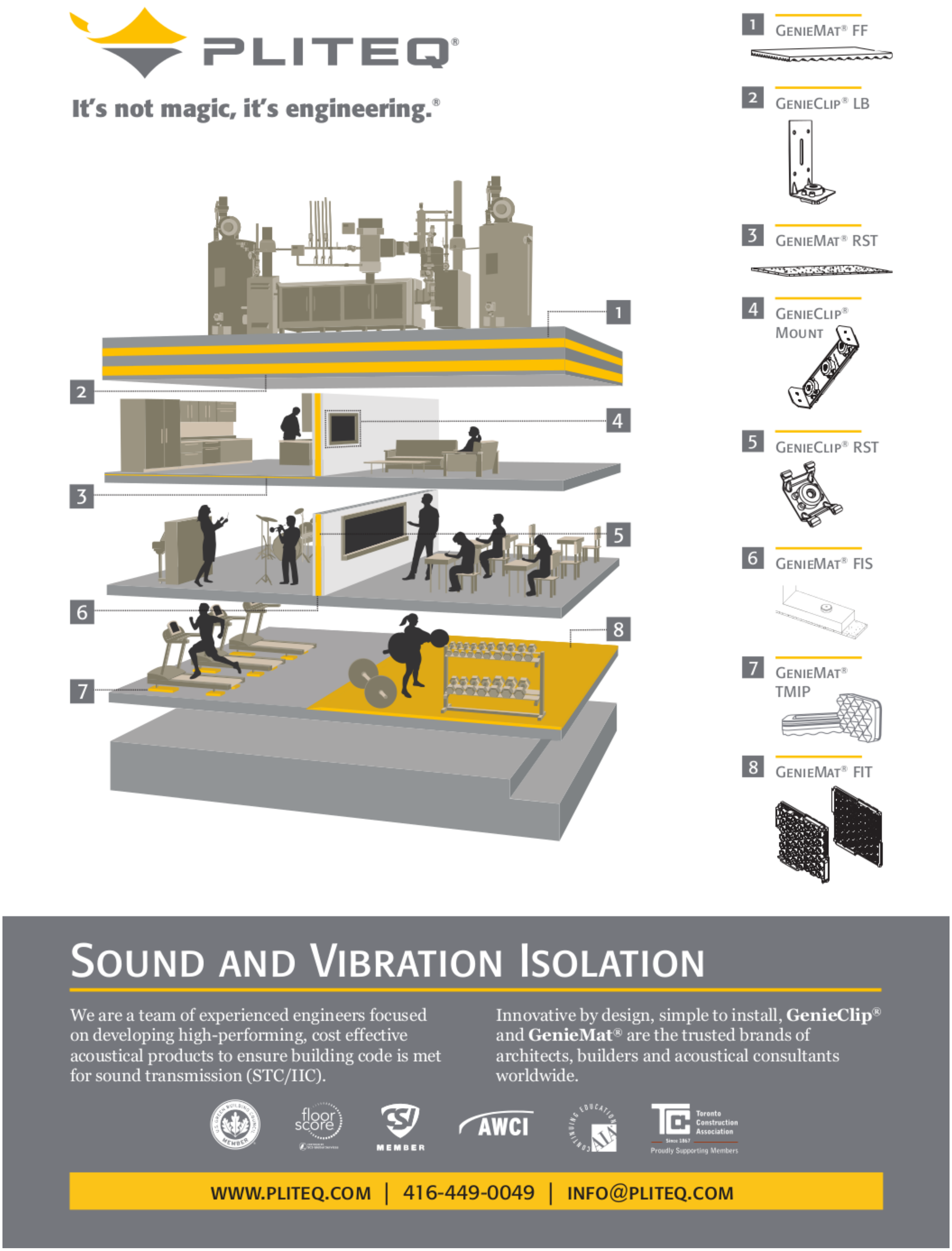


Figure 7: Frequency and its relationship with aeroacoustic issues.

The frequency of noise has an associated wavelength. For a building element to radiate noise efficiently, the dimensions of the element should be comparable to the wavelength of noise. For this reason, we can rule out many architectural features based on their dimensions. For audible noise generation, an architectural feature must have dimensions:

- Approximately less than 3 m for cavity resonance;
- As a general rule of thumb, any flexible spans, approximately 650 mm in diameter or less, have the potential to generate noise caused by vortex shedding.

Audible sounds having many frequencies at once, such as wind blowing through trees (broadband spectral sound) is often less annoying because it blends into the background noise, whereas sound consisting of one main frequency, or tonal noise tends to stand out. Thus, when assessing the risk of features in generating aeroacoustic noise we are generally assessing the likelihood of the feature generating strong tonal noise.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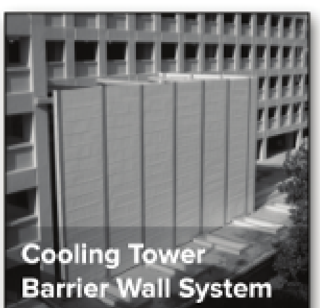

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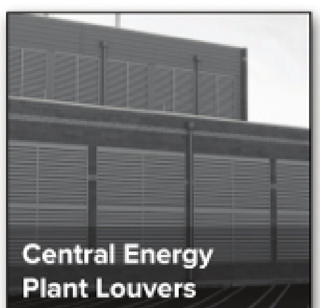

Central Energy
Plant Louvers

Equipment Yard
Noise Control

Cyclic Movement Primitives Underlying Two-Handed Alternating Signs In Signed Languages

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1 Introduction

In speech, biomechanical constraints shape phonetics-phonology. For example, English /r/ variants are selected based on minimizing biomechanical effort [1] and a single motor action in the tongue may govern multiple speech events to improve movement efficiency [2]. We propose that signed languages are similarly constrained by biomechanics. Specifically, the present paper considers the hypothesis that otherwise unexplained universal aspects of sign languages can be understood as resulting from a preference for repeated alternating arm movements triggered by vestigial locomotor CPGs developed in human ancestors for quadrupedal locomotion.

2 Background

Central pattern generators (CPGs) are networks of nerve cells located in the spinal cord often associated with control of repetitive or cyclic mostion, such as locomotion [3]. CPGs operate without any conscious effort, and do not require involvement of the brain: even dead bodies or bodies with the connection between the brain and the spine cut can walk if secured on a treadmill [4]. Although humans are bipedal, human hands still maintain vestigial traits of quadrupedalism, which surface in the coordination of arms and legs in walking, running and swimming [5]. CPGs in arms operate in ways similar to CPGs in legs [6]. In walking, swinging arms out of phase to legs helps to stabilize walking and is more energy-efficient [7]. Moreover, arm muscles activate during walking even when the arms are constrained [8, 9]. As such, we might well expect them to affect other manual activities using the forelimbs, such as the conventionalized manual movement systems used in natural sign languages of the deaf.

Signs in signed languages can be one- or two-handed. In two-handed signs, the non-dominant hand can be either passive (used as a place of articulation for the dominant hand) or active (where both hands have the same ("balanced") handshapes and move in a similar fashion) [10]. It is this last type of sign, "two-handed balanced" signs, that we consider in the present study. Importantly, in two-handed balanced signs, the hands can move either symmetrically/in-phase or alternatingly/anti-phase.

One might expect two-handed balanced signs to be rare, as moving two hands as opposed to one doubles the moving mass, thereby doubling the articulatory effort. This also requires the biggest reactive effort to stabilize the torso against the incidental movement induced by the moving hands [11]. And yet, such signs are quite frequent (in ASL such signs constitute about one third of the lexicon ([12], also see below). Balanced signs tend to resist change, either in phonological or historical processes, and are preferred in both first and second language acquisition [13, 14]. And some unbalanced signs become balanced over time [15, 16].

Two-handed balanced signs are not one unified group, and include signs with both symmetrical/in-phase and alternating/anti-phase movement. Evidence has accumulated for decades that balanced symmetrical signs and balanced alternating signs have different properties; e.g., some phonological processes (e.g., *weak drop*, where the non-dominant hand is dropped from the sign production) can be applied to signs with symmetrical but not with alternating movement [10, 17]. The same resistance to weak drop in alternating signs is found in first language acquisition of ASL [18]. And phonological processes that turn one-handed signs into two-handed signs (e.g., the Characteristic Adjective derivation in ASL) result in alternating signs, but not symmetrical signs [16].

If two-handed signs are influenced by locomotive CPGs, knowing that these govern repetitive movements, we can predict that in two-handed signs with both hands moving, the alternating movements will tend to be repeated and symmetrical, non-alternating movements to be single. We test this prediction with data from ASL and HKSL.

3 Method

We coded all signs from major dictionaries of two natural, unrelated sign languages of the deaf, American (ASL) [19] and Hong Kong Sign Language (HKSL) [20]. All signs were annotated for being one-handed (1h), two-handed unbalanced (2hb) and two-handed balanced (2hb). The latter were further annotated for movement pattern, single/repeated movement, plane of articulation (vertical, horizontal, etc.), iconicity (that is, their form resembles their meaning) (yes/no), and whether the sign was compound. Two types of signs were articulated on the horizontal plane and were coded as either symmetrical mirror movement (the two hands move away/toward each other on the horizontal plane), or symmetrical horizontal movement (the two hands move together synchronously leftwards/rightwards on the horizontal plane). These two groups of signs rely on different patterns from locomotion, and we do not discuss them here. The rest of the 2hb signs were coded as having symmetrical movement (the hands move in the same

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direction at the same time), alternating movement (the hands move in the opposite directions), or none. The ASL dictionary [20] consisted of 4217 signs, of which 1407 (33%) were 2hb. Of the 2hb signs, 359 (25.5% of 2hb) were symmetrical and 217 (15.4% of 2hb) were alternating. The HKSL dictionary [20] had 1861 signs, of which 498 (27%) were 2hb. Of the 2hb signs, 83 (17% of 2hb) were symmetrical and 70 (14%) were alternating.

4 Results

For both languages, alternating signs showed a significantly greater tendency for repeated movement than symmetrical signs (Table 1 and Figure 1). Chi-squared tests indicate that, for both ASL and HKSL, the difference between single- versus repeated-movement signs proportions was significant (for ASL : $\chi^2(1) = 131.5217$, $p < 0.05$; for HKSL : $\chi^2(1) = 11.2091$, $p < 0.05$).

Table 1: The distribution of movement types in ASL and HKSL.

ASL	Single	Repeated	Iconic
Symmetrical	274, 76%	85, 24%	125, 35%
Alternating	60, 28%	157, 72%	73, 34%
HKSL	Single	Repeated	Iconic
Symmetrical	51, 61%	32, 39%	37, 44.5%
Alternating	24, 34%	46, 66%	20, 28.5%

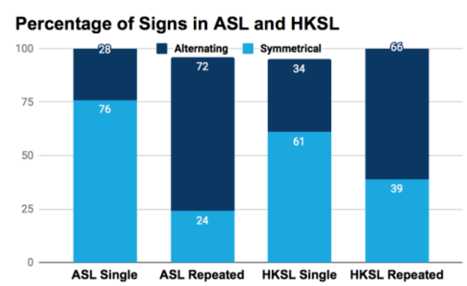

Figure 1: Proportions of signs with single and repeated movements in ASL and HKSL.

5 Discussion

This study shows that two-handed balanced signs, traditionally treated in sign-language linguistics as one group, have different movement tendencies depending on whether they are symmetric or alternating. In symmetric/in-phase signs, the hand movement tends to be single. In alternating/out-of-phase signs the movement tends to be repeated. A possible alternative explanation for these results could be iconicity. Previous studies showed that signs with inherent plural meaning favor two-handed forms [21]. In principle, iconicity can also favor movements that are single or repeated, but the proportion of iconic signs is comparable for both types of signs. We, therefore, explain our results with the view that two-handed signs are influenced by vestigial locomotor CPGs. As alternating bimanual movements are influenced by locomotor patterns, they favor repeated movements.

Acknowledgments

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References

[1] Stavness, I., Gick, B., Derrick, D. & Fels, S. S. Biomechanical modeling of English /r/ variants. *J. Acoust. Soc. Am.* 131(5): EL355-360, 2013.

[2] Derrick, D., I. Stavness & B. Gick. Three speech sounds, one motor action: evidence for speech-motor disparity from English flap production. *J. Acoust. Soc. Am.* 137: 1493-1502, 2015.

[3] Grillner S (1985) Neurobiological bases of rhythmic motor acts in vertebrates. *Science* 228: 143-50.

[4] MacKay-Lyons M (2002) Central pattern generation of locomotion: a review of the evidence. *Phys. Ther.* 82(1): 69.

[5] Emmerik RE, Wagenaar RC, Wegen EE (1998) Interlimb coupling patterns in human locomotion: are we bipeds or quadrupeds?. Ann N Y Acad Sci 860(1): 539-42.

[6] Delcomyn F (1980) Neural basis of rhythmic behavior in animals. Science 210(4469):492-8.

[7] Meyns P, Bruijn SM, Duysens J (2013) The how and why of arm swing during human walking. Gait Posture 38(4):555-62.

[8] Ballesteros ML, Buchthal F, Rosenfalck P (1965) The pattern of muscular activity during the arm swing of natural walking. Acta Physiol Scand 63(3): 296-310.

[9] Kuhtz-Buschbeck JP, Jing B (2012) Activity of upper limb muscles during human walking. J Electromyogr Kinesiol 22(2): 199-206.

[10] Battison R (1974) Phonological deletion in American sign language. Sign Language Studies 5(1): 1-9.

[11] Sanders N, Napoli DJ (2016) Reactive effort as a factor that shapes sign language lexicons. Language 92(2): 275-297.

[12] Klima E, Bellugi U (1979) The signs of language. Harvard University Press.

[13] Cheek A, Cormier K, Repp A, Meier RP (2001) Prelinguistic gesture predicts mastery and error in the production of early signs. Language 292-323.

[14] Pichler DC, Watkins M, Taylor S, Dicus D, Dudley S (2016) Refining Coding Criteria for Phonological Accuracy of L2 Signing. Theoretical Issues in Sign Language Research 12.

[15] Frishberg N (1975) Arbitrariness and iconicity: historical change in American Sign Language. Language 696-719.

[16] Padden CA, Perlmutter DM (1987) American Sign Language and the architecture of phonological theory. Nat Lang Linguist Theory 5(3): 335-75.

[17] Brentari D (1998) A prosodic model of sign language phonology. Mit Press.

[18] Siedlecki Jr T, Bonvillian JD (1993) Phonological deletion revisited: Errors in young children's two-handed signs. Sign Language Studies 80(1): 223-42.

[19] Costello E, Tom LC, Setzer PM (1994) Random House Webster's American Sign Language Dictionary. Random House.

[20] Tang G (2007) Hong Kong Sign Language: A trilingual Dictionary with Linguistic Descriptions. The Chinese University Press.

[21] Börstell, C., Lepic, R., & Belsitzman, G. (2016). Articulatory plurality is a property of lexical plurals in sign language. Lingvisticæ Investigationes, 39(2), 391-407.

VISUAL-AEROTACTILE PERCEPTION AND HEARING LOSS

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1 Introduction

Previous research on multimodal speech perception with hearing-impaired individuals has focused on audiovisual integration, with mixed results. Some evidence suggests cochlear-implant users integrate audiovisual cues better than perceivers with normal hearing when perceiving congruent [1] but not incongruent cross-modal cues [2], leading to the suggestion that early auditory exposure is required for typical speech integration processes to develop [3]. If a deficit of one modality leads to a general deficit in multimodal processing, then hard-of-hearing perceivers should show atypical patterns of integration in other modality pairings.

To test this, the current study builds on evidence that aerotactile information influences the perception of English stop consonants in normal hearing (NH) individuals. When perceiving auditory [4] or visual cues [5] to English stops, subjects are more likely to judge tokens as aspirated when they feel a simultaneous puff of air on the skin. These additional modality pairings (audio-aerotactile and visual-aerotactile) provide an opportunity to assess previous claims regarding the effects of impaired audition on sensory integration in speech perception. To better understand how individuals with hearing loss process multimodal information more generally, an integration task is required that does not rely on auditory input. Thus, a visual-aerotactile task such as that used by [5] is particularly well suited for hearing-impaired individuals who have normal perceptual experiences with both the visual and aerotactile modalities. If atypical auditory access in development leads to atypical integration processes across the board, then individuals with hearing loss should show different patterns of integration from individuals with typical hearing, regardless of the modality pairing.

2 Method

11 participants with hearing loss (HL) and 14 native English speakers with normal hearing (NH) were recruited from the Greater Vancouver area. The HL participants varied in the cause of hearing loss: 8 reported congenital hearing loss and the remaining 3 reported losing their hearing before the age of 10. The HL group further differed in the type of hearing loss. Nine HL participants reported sensorineural hearing loss, 1 participant reported mixed hearing loss, and 1 additional participant was unsure. Finally, participants varied in the severity of their hearing loss. Four participants reported profound hearing loss; 3 severe; 4 moderate; and 1 mild/moderate. All participants wore hearing aids and reported English as their principal communication method. No NH participants reported a history of speech or hearing issues.

Participants were seated in a sound-attenuated booth with their heads resting against a headrest and told they would feel puffs of air throughout the experiment. Participants completed a two-alternative forced-choice response task while listening to babble over headphones. During the task, participants were presented with 240 silent video clips of a male speaker producing the syllables /pa/ and /ba/. After each clip, participants used the keyboard to indicate what they thought the talker had said (i.e., /pa/ or a /ba/). Half of the clips were accompanied by a 100 ms duration puff of air directed at the participant's suprasternal notch (see [5] for details regarding the air flow apparatus and stimuli creation).

Following the perception task, HL participants completed both a language background questionnaire and a hearing history questionnaire. NH participants completed the language background questionnaire only.

3 Results

For both groups, participants showed increased accuracy for /pa/ tokens and decreased accuracy for /ba/ tokens during VT trials (Figure 1) – aerotactile cues facilitated aspirated syllable identification and interfered with unaspirated syllable identification. A generalized linear mixed effects model was fit by maximum likelihood using the lme4 [6] packaged in R [7]. Response served as the dependent variable; visual (/ba/ or /pa/), condition (visual-only or visual-tactile), group (HL or NH) and their interaction were fixed effects; and participant and a by-participant random slope for the interaction of visual, condition, and group were the random effects. The formula is as follows:

*Response ~ visual * condition * group + (1 + (visual * condition * group) | subject)*

To find the optimal model, model fitting was performed in a stepwise backward iterative way. The Akaike information criterion (AIC) was used to measure quality of fit. We found no significant difference of hearing group on response. In fact, the optimal model was one that excluded hearing group. Thus, the following results reflect a model that does not consider hearing ability. The model indicated that

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participants were most likely to respond correctly for /pa/ in a visual-tactile condition than all other conditions (β = 1.95, SE = 0.49, z = 3.96, p < 0.001) regardless of hearing group (see Figure 1). That is, aerotactile information facilitated identification of /pa/ for all participants.

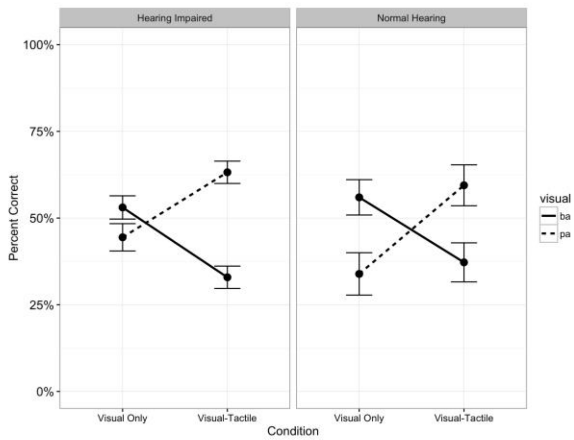

Figure 1: Percentage of correct responses in each condition (e.g., responding /ba/ when presented with a /ba/-visual cue). Accuracy for visual-only vs. visual-tactile conditions for both the hearing loss group (left) and the normal hearing group (right) are shown.

Given the high confusability between the articulations of /p/ and /b/, we predicted that participants would perform at chance at identifying the visual cues. However, both NH and HL participants were better at identifying /ba/ than /pa/ (β = -0.75, SE = 0.3, z = -2.46, p = 0.01), consistent with the ba-bias found in [5].

4 Discussion

This study investigated whether HL individuals show different multimodal integration patterns from NH perceivers during using a speech perception task without an auditory component. Our results show that HL participants are able to use aerotactile information when identifying visual bilabial articulations, demonstrating their ability to integrate cross-modal speech cues. More to the point, we found no significant difference between HL and NH individuals suggesting that reduced auditory access may not affect the development of typical speech integration processes. While we were unable to conduct in-house audiometry for each participant and therefore cannot make strong claims about what kind of acoustic information each participant would be exposed to, the strength and uniformity in the performance of the HL group in visual-tactile integration reaffirm that the development of multimodal integration processes is not contingent on hearing ability. This evidence that individuals with hearing loss have normal multimodal speech processing suggests that previous atypical performance at audiovisual integration tasks may be attributed to the degraded quality of audio input given their hearing loss and a subsequent reliance on visual cues.

However, there are some limitations to our study. The HL participants in this experiment may not be representative of previous research given that they differed greatly in hearing ability. Many had residual hearing and used hearing aids to communicate orally. This is a very different population from the cochlear implant users in previous research [1, 2, 3, 8, 9], who were mostly congenitally deaf individuals with profound hearing loss. It is possible that the residual hearing ability of the HL participants in the current study may provide enough auditory input for them to develop speech experiences similar to normal hearing participants. Given this variability, future directions should extend the research to the profoundly deaf.

5 Conclusion

The present study examined multimodal speech perception in individuals with hearing loss through a visual-tactile integration task. Results showed that participants used aerotactile stimuli as a cue to aspiration and integrated visual and aerotactile speech cues as in [5]. In addition, there were no differences in the integration pattern between normal hearing subjects and subjects with hearing loss suggesting that HL individuals can make use of the same visual and tactile cues to stop discrimination in English and have normal multimodal processing for speech information.

Acknowledgments

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References

[1] Rouger, J., Lagleyre, S., Fraysse, B., Deneve, S., Deguine, O., & Barone, P. (2007). Evidence that cochlear-implanted deaf patients are better multisensory integrators. *Proc. of the Nat. Acad. of Sci., 104*(17), 7295-7300.

[2] Rouger, J., Fraysse, B., Deguine, O., & Barone, P. (2008). McGurk effects in cochlear-implanted deaf subjects. *Brain research*, 1188, 87-99.

[3] Schorr, E. A., Fox, N. A., van Wassenhove, V., & Knudsen, E. I. (2005). Auditory-visual fusion in speech perception in children with cochlear implants. *Proc. of the Nat. Acad. of Sci., 102*(51), 18748-18750.

[4] Gick, B., & Derrick, D. (2009). Aero-tactile integration in speech perception. *Nature, 462*(7272), 502-504.

[5] Bicevskis, K., Derrick, D., & Gick, B. (2016). Visual-tactile integration in speech perception: Evidence for modality neutral speech primitives. *JASA*, 140(5), 3531-3539.

[6] Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, 67(1), 1-48. doi: <10.18637/jss.v067.i01>.

[7] R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org/>.

[8] Huyse, A., Berthommier, F., & Leybaert, J. (2013). Degradation of labial information modifies audiovisual speech perception in cochlear-implanted children. *Ear and hearing, 34*(1), 110-121.

[9] Lane, H., & Perkell, J. S. (2005). Control of voice-onset time in the absence of hearing: a review. *Journal of Speech, Language, and Hearing Research, 48*(6), 1334-1343.

A Biomechanical Model For Infant Speech And Aerodigestive Movements

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1 Introduction

Speech is arguably the most complex voluntary movement behavior in the natural world. A central question in speech research is how infants are able to learn speech movements so rapidly and with such limited input.

Computational modeling has become an increasingly promising method for understanding adult speech. Biomechanical modeling allows researchers to study realistic 3D models of the vocal tract built from anatomical and physiological data from perspectives that are difficult to achieve otherwise. Biomechanical modeling of the infant vocal tract will enable similar research into questions relating to speech acquisition.

For example, one appealing proposal regarding speech acquisition is that some core speech movements may build on phylogenetically-encoded aerodigestive actions such as breathing, swallowing and suckling [1, 2]. The idea that neuromuscular primitives such as those relating to digestion are used to bootstrap more complex movement has been suggested in other domains [3, 4], and proposing it as a mechanism in speech acquisition is in accord with neurological [5], clinical [6], and kinematic [7] evidence relating speech and aerodigestive movements.

This hypothesis has proven difficult to test, in part because the anatomy of the vocal tract makes most standard methods such as EMG too invasive or imprecise. The development of biomechanical models of the vocal tract has recently allowed researchers to evaluate some of the predictions made by this hypothesis, showing, for example, that swallowing and movements used in speech occupy similar areas in muscle activation space [8]. A shortcoming of this research is that it has used models of an adult vocal tract to test proposals about infant speech. Adult and infant vocal tracts differ not only in their size, but also in the relative proportions of their structures [9, 10].

In this paper we present a preliminary model of an infant vocal tract using the 3D biomechanical simulation platform Artisynth (e.g. [11, 12]). This model is generated by modifying an existing vocal tract model implemented in Artisynth to conform to the proportions of a mid-sagittal CT image of an infant vocal tract. The model will be capable of simulating both swallowing and simple speech movements, and the results of simulations using this model will provide useful insight into infant motor control, supplementing evidence from other domains.

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2 Methods

Artisynth contains a model of an adult vocal tract called Frank [13]. We used Frank as a starting point, modifying its relative proportions to match more closely those of an infant. To determine the proportions, we compared a mid-sagittal CT image of an 11-month-old male infant vocal tract to a mid-sagittal image of the Frank vocal tract. A set of twelve biometric measurements were modified from previous studies of infant vocal tract development [9, 10].

These measurements were (1) *vocal tract length*: the curvilinear distance along the midline of the vocal tract from the superior point of the larynx to a line tangential to the incisors; (2) *hard palate length*: the curvilinear distance along the hard palate contour from the anterior base of the incisor to the beginning of the soft palate; (3) *soft palate length*: the curvilinear distance along the soft palate contour from the posterior edge of the hard palate to the inferior edge of the uvula; (4) *mandibular length*: the length of a straight line from the mental protuberance to the anterior point of the thyroid cartilage; (5) *tongue length*: the curvilinear distance along the tongue surface from the vallecula to the tongue tip; (6) *hyoid height*: the vertical distance from the posterior nasal spine to the superior edge of the hyoid bone; (7) *larynx height*: the vertical distance from the posterior nasal spine to the superior edge of the vocal folds; (8) *oropharynx length*: the vertical distance from the inferior edge of the uvula to the superior edge of the vocal folds; (9) *vocal tract horizontal length*: the horizontal distance from a line tangent to the incisors to the back of the nasopharynx; (10) *anterior cavity length*: the horizontal distance from a line tangent to the incisors to the intersection with a vertical line from the anterior edge of the glottis to the palate; (11) *oropharynx width*: the horizontal distance from the back of the nasopharynx to the intersection with a vertical line from the anterior edge of the glottis to the palate; and (12) *mandible height*: the length of a straight line from the inferior point of the mandible to the superior point of the lower incisors.

Because the images at are different scales, all measurements were normalized by dividing each distance by the mandible height. The infant and Frank vocal tracts with measurements overlaid are shown in Figure 1.

The most substantial difference between the infant and Frank vocal tracts is that the larynx and hyoid are higher in the infant. This is reflected in the *vocal tract length*, *hyoid level*, *larynx level*, and *oropharynx length* measurements.

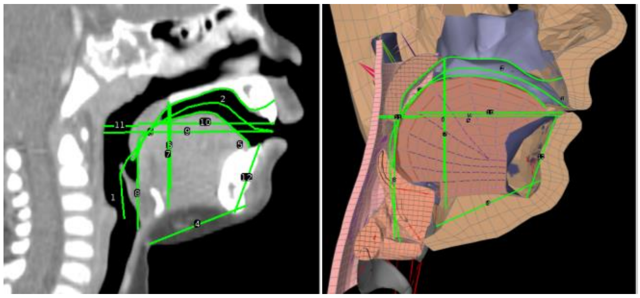

Figure 1: The infant vocal tract (left) and Frank vocal tract model (right) with overlaid measures.

In order to quantify similarity between the infant vocal tract and the Artisynth models, we designed a measure θ similar to the sum of squared errors:

$$\theta = \sum_{i=1}^{m} I_i \,(M_i - I_i)^2$$

Where i indexes over the set of measurements, M_i is the normalized measurement from the model, and I_i is the normalized measurement from the infant CT image. This measure penalizes differences in larger measurements more than differences in shorter measurements, and lower values indicate a closer correspondence to the infant vocal tract.

The structures in the Frank vocal tract were manually modified using rigid body translations and affine transformations to bring them in line with the proportions of the infant vocal tract. We also removed excess tissue, including the face. The same measurements were then carried out on the infant vocal tract model and compared to those of the original Frank model (Figure 2).

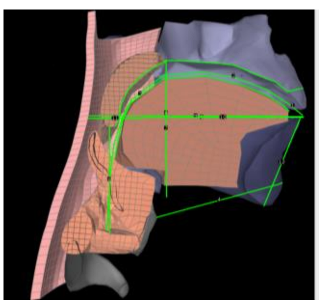

Figure 2: Infant vocal tract model with overlaid measures.

3 Results

For the original Frank model, θ = 1.438, while the infant vocal tract model, θ = 0.373. This indicates that the infant vocal tract model in Artisynth corresponds more closely to the dimensions of the infant vocal tract than the original Frank model.

4 Discussion and future work

The infant vocal tract model presented in this paper will allow researchers to simulate both aerodigestive and speech movements. The results of these simulations will help to supplement neurological, clinical, and kinematic evidence bearing on hypotheses relating to the acquisition of speech and aerodigestive movements. In addition, we plan to further increase the accuracy of the infant model by validating the muscle insertions and replacing the maxilla and mandible with 3D models generated from infant data.

Acknowledgments

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References

[1] MacNeilage, P. (2008). *The Origin of Speech*. Oxford and New York: Oxford University Press.

[2] Studdert-Kennedy, M., & Goldstein, L. (2003). Launching language: The gestural origin of discrete infinity. In M. Christiansen & S. Kirby (Eds.), *Language Evolution*. Oxford and New York: Oxford University Press.

[3] Wolpert, D.M., Ghahramani, Z., & Flanagan, J.R. (2001). Perspectives and problems in motor learning. *TRENDS in Cognitive Science, 5*(11), 487-94.

[4] Dominici, N., Ivanenko, Y.P., Cappellini, G., d'Avella, A., Mondi, V., Cicchese, M., Fabiano, A., Silei, T., Di Paolo, A., Giannini, C., Poppele, R.E., & Lacquaniti, F. (2011). Locomotor Primitives in Newborn Babies and Their Development. *Science, 334*(6058), 997-9.

[5] Martin, R.E., MacIntosh, B.J., Smith, R.C., Barr, A.M., Stevens, T.K., Gati, J.S., & Menon, R.S. (2004). Cerebral areas processing swallowing and tongue movement are overlapping but distinct: a functional magnetic resonance imaging study. *J. Neurophysiology, 92*(4), 2428-43.

[6] LaGorio, L.A., Carnaby-Mann, G.D., Crary, M.A. (2008). Cross-system effects of dysphagia treatment on dysphonia: a case report. *Cases Journal, 1*(1):1-67.

[7] Green, J.R., Moore, C.A., Higashikawa, M., & Steeve, R.W. (2000). The Physiologic Development of Speech Motor Control: Lip and Jaw Coordination. *J. of Speech, Language & Hearing Research, 43*(1), 239-55.

[8] Mayer, C., Roewer-Despres, F., Stavness, I., & Gick, B. (2017). Do innate stereotypies serve as a basis for swallowing and learned speech movements? *Behavior and Brain Sciences, 40*.

[9] Vorperian, H.K., Kent, R.D., Lindstrom, M.J., Kalina, C.M., Gentry, L.R., & Yandell, B.S. (2005). Development of vocal tract length during early childhood: A magnetic resonance imaging study. *J. Acous. Soc. Am., 117*(1), 338-50.

[10] Vorperian, H.K., Wang, S., Chung, M.K., Schimek, E.M., Durtschi, R.B., Kent, R.D., Ziegert, A.J., & Gentry, L.R. (2009). Anatomic development of the oral and pharyngeal portions of the vocal tract: An imaging study. *J. Acous. Soc. Am, 125*(3), 1666-78.

[11] Stavness, I., Lloyd, J.E., & Fels, S.S (2012). Automatic Prediction of Tongue Muscle Activations Using a Finite Element Model. *J. Biomechanics, 45*(16), 2841-8.

[12] Gick, B., Anderson, P., Chen, H., Chiu, C., Kwon, H.B., Stavness, I., Tsou, L., & Fels, S. (2014). Speech function of the oropharyngeal isthmus: A modeling study. *Computer Methods in Biomechanics & Biomedical Engineering: Imaging & Visualization, 2*(4), 217-22.

[13] Anderson, P., Fels, S., Harandi, N.M., Ho, A., Moisik, S., Sanchez, C.A., Stavness, I., Tang, K. (2017). FRANK: a hybrid 2D biomechanical model of the head and neck. In Y. Payan & J. Ohayon (Eds.), *Biomechanics of Living Organisms.* Academic Press, 413-47.


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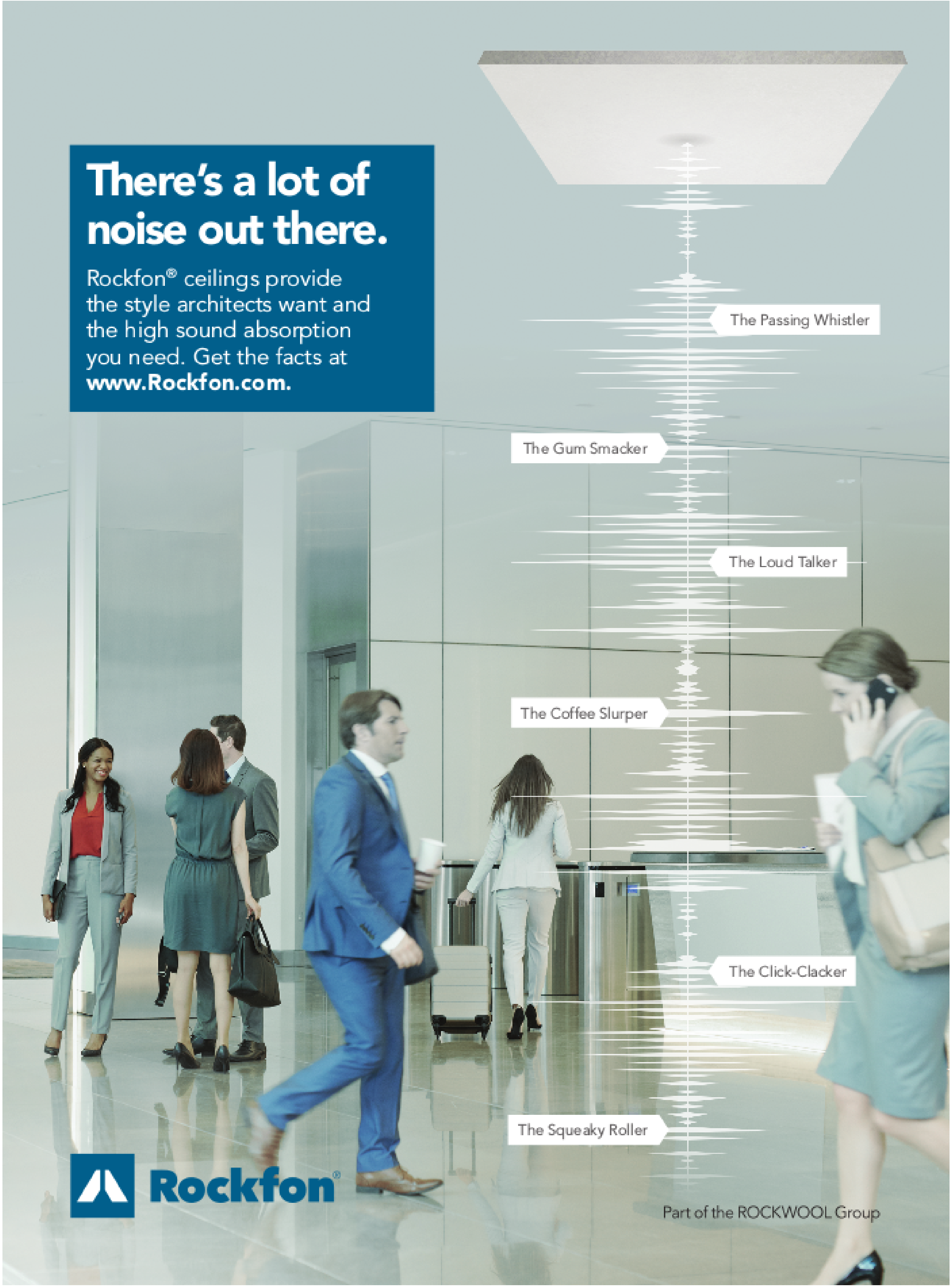
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VOWEL LENGTH DISTINCTIONS IN PLAINS CREE

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1 Introduction

Cree is a dialect continuum spoken across much of Canada, from British Columbia to Labrador. Cree inherited from Proto-Algonquian a phonological contrast between "long" and "short" vowels which is equivocal in nature [1]. Long/short pairs are notoriously distinct in the vowel spaces of Eastern dialects [2]. In Northern East Cree, for instance, "this distinction is realized as a contrast in vowel quality: historically long vowels have become tense and historically short vowels are lax" [3].

For Western dialects, too, Muehlbauer [4] warns that "we should not treat the purely durational analysis ... as a foregone conclusion." He conducted a pilot acoustic study of Plains Cree vowels (/aː, a, oː, o, iː, i, eː/) based on mid-20th-century recordings of three women from Alberta and Saskatchewan. While there is "strong use of duration to contrast long and short pairs of phonemes, ... all vowel pairs also differ in terms of their quality – either F1, F2, or both" [4].

Harrigan & Tucker [5] ran a similar pilot study of Plains Cree vowels with three women from Maskwacis, Alberta, with similar results, except that the pair /oː/–/o/ showed no reliable differences in quality—only quantity.

This paper reports on a third pilot study, based on publically available recordings of two noted teachers of Plains Cree: Mrs. Dolores Sand from Muskeg Lake Cree Nation in central Saskatchewan, and Dr. Jean Okimasis from White Bear First Nation in southern Saskatchewan. Both were raised with Plains Cree as a first language. Mrs. Sand was recorded when she was 58 years old [6], and Dr. Okimasis when she was 60 [7].

2 Method

We used Praat [7] to annotate and measure vowels and adjacent consonants extracted from the first ten minutes of narration by Mrs. Sand [4], and a corresponding number of tokens from Dr. Okimasis uttering words and phrases (workbook sessions 10, 11, 13) [5]. We did not restrict ourselves to vowels flanked by particular consonants (cf. /t, k/ in [4]; /t, s/ in [5]), but we avoided word-final vowels as well as vowels intertwined with /h, j, w/. We also avoided instances of syncope, which can result in compensatorily lengthened consonants (cf. [3]). We used a Praat script that reported mean formant values only in the middle 60% portion of vowels, to reduce effects from consonant transitions and anticipatory vocalic assimilation. The latter co-articulatory effect is rather forceful Plains Cree, as illustrated in Fig. 1.

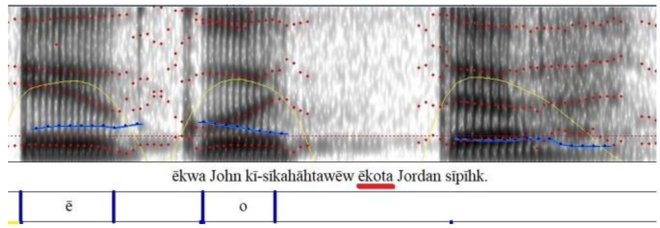

Figure 1: Anticipatory vocalic assimilation in Plains Cree *ēkota*

3 Results

3.1 Vowel quality

As shown in Fig. 2, Mrs. Sand clearly differentiates all vowels in terms of quality, except that the standard deviation of /o/ encompasses that of /oː/. This confirms what Muehlbauer found: "while the hypothesized short/long vowel pairs do indeed have a strong durational contrast, the majority of vowel pairs are also distinguished by their formants. In all cases, the long vowel occupies a more extreme position in the vowel space. Plains Cree thus appears to show both a quantity and a quality contrast in its vowel pairs" [4].

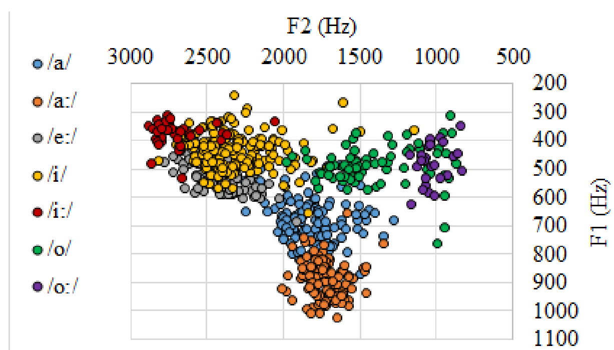

Figure 2: Vowel qualities (non-final position) – Dolores Sand

As shown in Fig. 3 on the next page, Dr. Okimasis also differentiates short/long pairs in terms of quality, but her vowel space shows far more overlap than Mrs. Sand's—particularly in the vowel pairs /o, oː/ and /a, aː/, as well as between them. This is similar to what Harrigan & Tucker [5] reported for Maskwacis, Alberta.

3.2 Vowel duration

Mrs. Sand and Dr. Okimasis both strongly differentiate all long/short vowel pairs in terms of duration, as shown in Figs. 4 and 5 on the next page. To give an idea, Mrs. Sand's

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/a:/ is generally 2.6 times longer than her /a/ (156 ms (N=114) vs. 59 ms (N=127)). Similarly, her /i:/ is 2.7 times longer than her /i/; and her /o:/ is 2.1 times longer than her /o/.

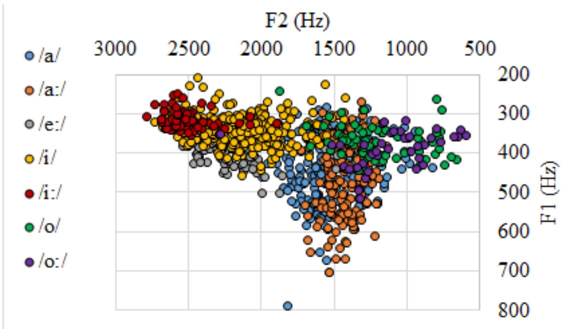

Figure 3: Vowel qualities – Jean Okimasis

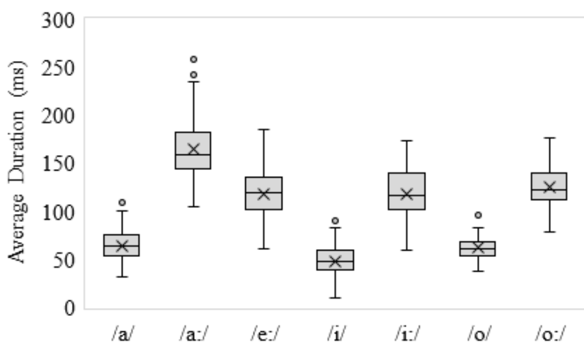

Figure 4: Vowel duration (non-final position) – Dolores Sand

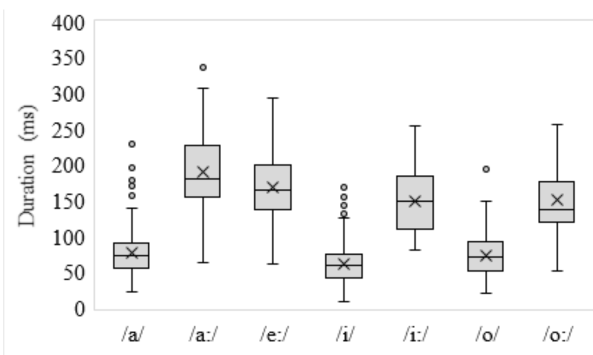

Figure 5: Vowel duration – Jean Okimasis

3.3 Contrast reduction

The striking durational difference between short and long vowels appears to be greatly reduced in closed syllables. In practice, only /s/ and /h/ may close a non-final syllables in Plains Cree. Table 1 illustrates this contrast reduction in Mrs. Sand's speech (with admittedly low Ns).

In practice, however, the durational difference between short and long vowels remains significant in closed syllables. On the other hand, coda consonants are a bit longer after short vowels, and/or they are a bit shorter after long vowels. The overall effect is a contrast reduction in the rhyme.

Table 1: Contrast reduction with VC. – Dolores Sand

/as./	/a:s./	/ah.C/	/a:h.C/
245 (N=8)	273 (N=4)	296 (N=13)	319 (N=11)
/is./	/i:s./	/ih.C/	/i:h.C/
213 (N=15)	241 (N=3)	255 (N=12)	270 (N=12)

Fig. 6 below illustrates this effect in Dr. Okimasis's speech. Durational differences are reduced but remain significant in short/long vowel pairs before syllable-final /s/ or /h/ (as simple t-tests reveal). However, durational differences between rhymes with short vs. long vowels are not always significant, particularly in syllables closed by /h/. This contrast reduction at the level of the rhyme is likely the basis for this remark from Wolfart [9]: "In the dialects of central Saskatchewan ..., vowel length tends to be indeterminate before preaspirated stops."

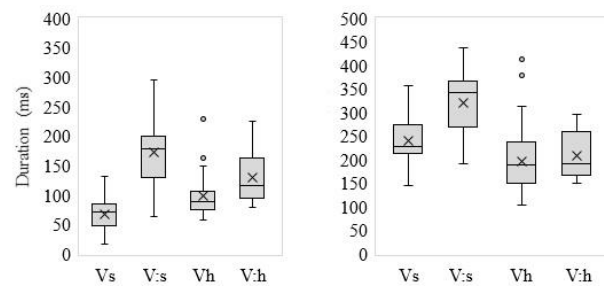

Figure 6: Nucleus vs. Rhyme duration – Jean Okimasis

References

[1] MacKenzie, M. 1980. *Towards a dialectology of Cree-Montagnais-Naskapi*. Doctoral dissertation, University of Toronto.

[2] Dyck, C., Junker, M.-O., & Logan, K. 2010. Phonetic and phonological evidence for a vowel merger in Southern East Cree. *UBC Working Papers in Linguistics* 29, 98–114. [2] Muehlbauer, J. 2012. Vowel spaces in Plains Cree. *Journal of the International Phonetic Association*, 42(3), 91–105.

[3] Knee, S. 2014. Vowel devocalization in Northern East Cree. *Canadian Journal of Linguistics*, 59, 303–338.

[4] Muehlbauer, J. 2012. Vowel spaces in Plains Cree. *Journal of the International Phonetic Association*, 42(1), 91–105.

[5] Harrigan, A. & Tucker, B. 2015. Vowels spaces and reduction in Plains Cree. *Canadian Acoustics*, 43(3), 1–2.

[6] Canadian Bible Society. 2010. *miywācimowin kā - kī-masinahahk Mark*. North York, ON: Canadian Bible Society.

[7] Okimasis, J. 1999. Cree, language of the Plains workbook. Regina, SK: University of Regina Press.

[8] Boersma, P. & Weenink, D. 2018. Praat: doing phonetics by computer [Computer program]. Version 6.0.43, retrieved 8 September 2018 from http://www.praat.org/

[9] Wolfart, H. C. 1996. Sketch of Cree, an Algonquian language. In Goddard, I. (ed.), *Handbook of American Indians*, Vol. 17: Languages, 390-439. Washington, DC: Smithsonian Institute.

DAGAARE [a] IS NOT NEUTRAL TO ATR HARMONY

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1 Introduction

Dagaare is a Gur language of the Niger-Congo family, part of a group of languages known as the Mabia languages. It is spoken by about 1.5 million people in northwestern Ghana and some parts of Burkina Faso [1,2].

Dagaare is described as having a nine-vowel inventory, with tongue root contrasts for high and mid vowels, but a single low vowel [a] [1,3]. Dagaare has ATR harmony, in which vowels within a phonological word agree in tongue root features, but the low vowel is described as being neutral to this phenomenon [1].

The present paper describes an acoustic study of <a> in Central Dagaare as spoken in Sombo, Nadowli-Kaleo district. Formants of <a> were measured in verbal particles surrounded by different combinations of ATR and RTR vowels. Results show that <a> is significantly higher and fronted when followed by an ATR vowel compared to when followed by an RTR vowel. This suggests that Dagaare <a> is not in fact neutral to harmony, but instead has two significantly different variants depending on whether it occurs in an ATR or RTR context, as in Figure 1.

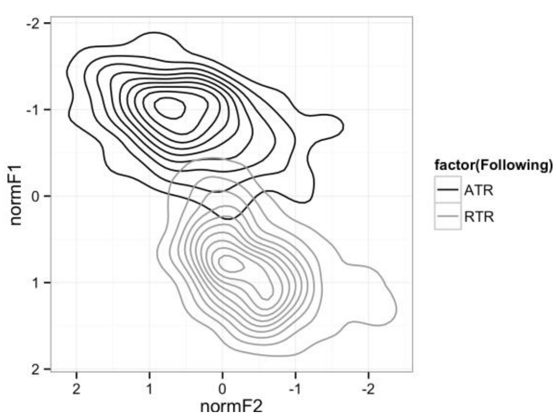

Figure 1: Normalised F1-F2 of <a> by following context

2 Methods

Data come from 5 male native speakers of Dagaare (ages 32 to 50). Data were collected in Nadowli-Kaleo district, Ghana. The data were elicited in a soundproofed room with a Shure WH30 headset microphone at a sampling rate of 48kHz: 16Bit.

The stimuli contain the target <a> in verbal particles, between different ATR/RTR combinations in carrier phrases. A sample of the stimuli is given in Table 1.

Table 1: Carrier phrases with <a> between ATR/RTR vowels

Preceding	Following	Target	Gloss
ATR	ATR	Báj[úó] **tá** [dí] dííbú	'Bájúó, don't eat food'
RTR	RTR	Bàj[ɔ̀ɔ̀] **tá** [dí]bɛ́ŋɛ́	'Bájọ̀ọ̀, don't take beans'
ATR	RTR	Dàb[ùó] **tá** [dí] à nɛ́n	'Dábùó, don't take meat'
RTR	ATR	Bàj[ɔ̀ɔ̀] **tá** [dí] dííbú	'Bàjọ̀ọ̀, don't eat food'

3 Results

Vowels of interest were segmented manually in Praat [4], and a script was used to extract F1 and F2 values at the 50% point. Since all particles behaved the same way, we combined them for the purposes of the analysis. The mean F1 and F2 values for each condition are given in Table 2.

Table 2: Average formant values in each condition

Preceding context	Following context	F1 (Hz)	F2 (Hz)
ATR	ATR	450.93	1567.66
RTR	ATR	463.84	1560.70
ATR	RTR	591.03	1450.36
RTR	RTR	613.73	1424.22

As is evident, F1 values are substantially higher when the following context is ATR than when it is RTR; F2 values in the same context are lower. There is also a slight, but much smaller, difference in F1 and F2 in the same directions based on preceding context.

Formant values were z-score normalized for each participant, in order to increase comparability across different speakers. The boxplot in Figure 2 shows normalized F1 by following context for all speakers and all particles; Figure 3 shows the same for F2. The same clear distinction as in Table 2 holds in these figures.

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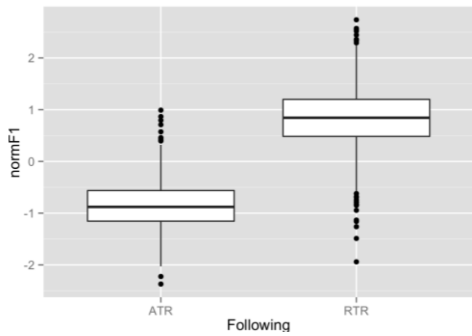

Figure 2: Normalized F1 by following context

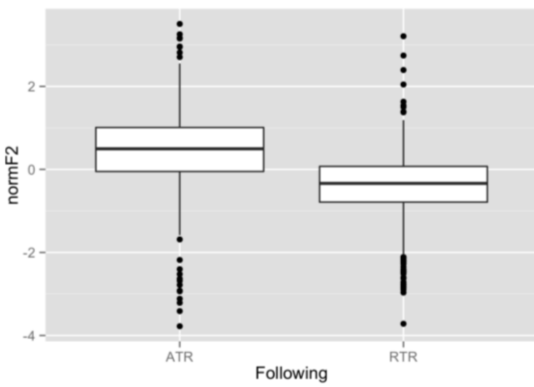

Figure 3: Normalized F2 by following context

We fit linear mixed effects models to determine the significance of these effects. The dependent variables were normalized F1 and F2, and the fixed effects were preceding context, following context, and their interaction. Subject and word were included as random effects, with preceding and following context as random slopes for both. ATR was used as the reference level for both fixed effect factors.

Following context was a significant effect on both normalized F1 and normalized F2 (t=11.060 and t=-6.165 respectively). The direction of the difference was positive for F1 and negative for F2, indicating that F1 is significantly higher while F2 is significantly lower with following RTR contexts, compared to following ATR contexts. Preceding context was not a significant effect on either of F1 or F2 (t=1.182, t=-0.310 respectively), nor was the interaction between preceding and following context (t=0.496, t=-0.738 respectively). Note that a t value above 2 is the cut-off for significance.

We additionally extracted formant measurements at the 25% and 75% points to confirm whether the effect is present through the entire vowel. As seen in Figure 4, there is a substantial difference in F1 value based on following context at all positions. Linear models with the same structure as described for the data from the 50% point were run for both the 25% and 75% point, confirming that the effect of following context on F1 and F2 is significant at all three points.

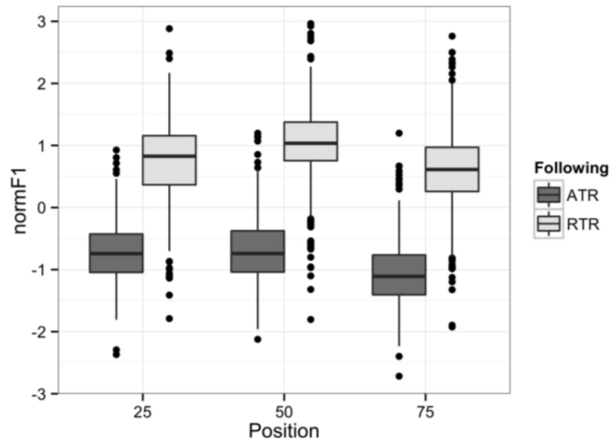

Figure 4: Normalized F1 by position and following context

4 Discussion and conclusions

The results show substantial, significant F1 and F2 differences for <a> in contexts where an ATR vowel follows versus ones with a following RTR vowel, suggesting that <a> is raised and fronted in ATR contexts. These differences were present for all speakers and all verbal particles. This suggests that Dagaare <a> is not a single vowel that is neutral to harmony. Instead, it is significantly different in RTR versus ATR contexts. Moreover, this difference is maintained throughout the vowel, suggesting that the effect is phonological, rather than phonetic coarticulation.

Overall, this study has shown that Dagaare [a] is not neutral to ATR harmony. Instead, there is a significant difference in <a> when it is followed by ATR versus RTR vowels; the former context is raised and fronted compared to the latter. This suggests the possibility that there are two low vowels in Dagaare, [a] in RTR contexts and [ʌ] in ATR contexts, which should be investigated in more detail in future work.

Acknowledgments

We would like to acknowledge Angsongna Yendor Roger, Anthony Duusuuri, and members of Kaleonaa family for sharing their language with us. This research is part of the project funded by SSHRC Insight grant (#435-2016-0369) awarded to Douglas Pulleyblank.

References

[1] Bodomo, Adams. The Structure of Dagaare. *Stanford Monographs in African Languages.*Stanford, CA: CSLI, 1997.

[2] Kennedy, Jack. Collected Field Reports on the Phonology of Dagaari. Collected. *Collected Language Notes.* vol. 6, 1966.

[3]. Kropp Dakubu, Mary Esther. *Collected language notes on Dagaare grammar* 26. University of Ghana: Institute of African Studies, 2005.

[4]. Boersma, Paul. *Praat, a system for doing phonetics by computer.* 9/10, s.l. : Glot International, vol. 5, pp. 341-345, 2001.

PAUSING AS A PROSODIC CORRELATE OF SPEECH UNITS IN ST'ÁT'IMCETS (LILLOOET SALISH)

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1 Introduction

The reliability of pausing as a correlate to prosodic, syntactic and discourse units has been debated in commonly-studied languages (outlined, for instance, in [1]). Preliminary research in Nxaʔamxčín (Interior Salish) [2] has shown that pausing could be a more reliable acoustic correlate of discourse structure than pitch, in line with previous research indicating that Salish languages do not exhibit a strong reliance on pitch to mark information structure [3-6].

The overall goal of this project is to document and analyse intonation patterns in St'át'imcets, to make available and useful the results for language teaching and to compare the results with other Interior Salish languages. The question explored in this study is what role (syntactic, prosodic, narrative) does pausing play in one St'át'imcets narrative [7]? Specifically, the hypotheses tested are:

1) More pauses will occur at clause boundaries than clause internally (following [8] cited in [9])

2) Pauses at narrative and syntactic boundaries will be longer than clause internally, and pauses at larger syntactic and narrative boundaries will be longer than at smaller boundaries (clause internal < clause boundary < sentence boundary < episode boundary) (following [10], [11])

3) There is a relationship between speech rate and pause duration (following [9])

4) There is a relationship between the duration of the preceding prosodic phrase and pause duration (as in [1]).

2 Method

2.1 Participant

The participant is a 74-year-old fluent speaker of the Tsal'álh dialect, from Nxwísten (Bridge River), Qwa7yán'ak (Carl Alexander).

2.2 Stimuli & experimental procedure

The material is a published 9.5-minute spontaneous narrative recorded in WAV format using a Marantz P MD660 and Carvin uni-directional microphone ([7]).

The narrative was segmented in ELAN following the syntactic breakdown.

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2.3 Acoustic Analysis

The recording was analysed in Praat on a MacBook Pro. Pitch settings were 40-400 Hz with a silence threshold of 0.1 due to the noisy recording. The recording was segmented into 9 episodes (marked by very long pauses and topic shifts), 19 stanzas (complete sentences) and 55 clauses (the core of a longer sentence that can stand on its own (e.g. minus adjuncts, and non-restrictive relative clauses)).

The duration of pauses longer than 250 ms was measured (following [9]) and classified for one of four syntactic locations: clause internal, clause boundary, sentence boundary or episode boundary. A subset of stanzas [12, 13, 15, 16] was analysed for a possible relationship between speech rate (syllables/second as measured across the sentence) and pause duration; and between speech duration (number of syllables in the preceding prosodic phrase) and pause duration.

3 Results

Of the 55 clauses identified, most exhibited pauses, with only 7 lacking pauses. Hypothesis 1 was supported: the majority of pauses, 47, or 59.5%, occurred at clause boundaries, while only 32, or 40.5%, occurred clause internally.

Table 1: Descriptive Data for Pause Duration

Pause location	Duration range (sec)	Mean (sec)	Std Dev	N
Clause internal	.28-7.9	1.67	1.4640214	32
Clause boundary	.43-6.3	1.73	1.3167972	28
Sentence boundary	.9-3.6	1.92	0.8878523	11
Episode boundary	5.58-33.2	13.31	10.223571	8

Table 1 shows descriptive statistics for each of the four possible syntactic pause locations. To test hypothesis 2, a one way analysis of variance (ANOVA) was conducted to compare the effect of syntactic location on pause duration. The analysis was significant ($F(3,75) = 28.33$, $p < 0.05$). Descriptively, the mean pause duration was shortest clause internally (1.67s) and gradually increased as the syntactic boundary type increased from clause (1.73s) to sentence (1.92s) to episode (13.31s). However, Tukey-Kramer pairwise comparisons indicated that hypothesis 2 was only partially supported. Pauses at episode boundaries were significantly longer than at each of the other three pause locations. On the other hand, clause internal pauses, pauses at clause boundaries, and pauses at sentence boundaries were not significantly different from one another (Figure 1).

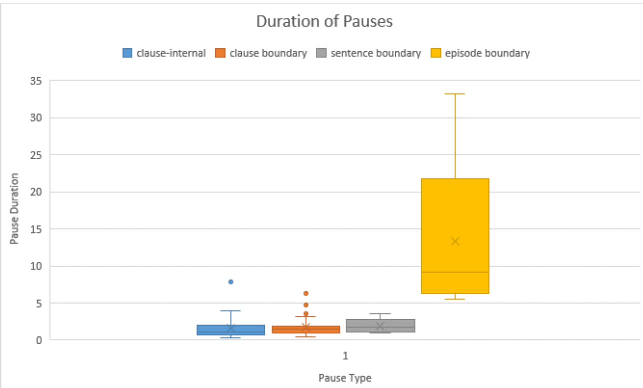

Figure 1: Duration of Pauses by Syntactic Location

To test hypothesis 3, a correlational analysis was conducted on pauses in 4 stanzas, to examine the relationship between speech rate (syllables/second) and pause duration. The analysis was significant ($r(11) = -0.71$, $p < 0.05$), indicating that as speech rate increased, pause duration decreased.

To test hypothesis 4, a correlational analysis was conducted on pauses in the same 4 stanzas, to examine the relationship between preceding speech duration (number of syllables in the preceding prosodic phrase) and pause duration. The analysis was not significant ($r(11) = -0.19$, $p > 0.05$).

4 Discussion

These results suggest that St'át'imcets fits into previous research on spontaneous narratives in some respects but not others. Most clauses are marked with pauses (see also [12] on SENĆOŦEN). 59.5% of pauses occur at clause boundaries as compared to 40.5% clause internally; this finding is similar to the rates of 55% of pauses at grammatical junctures and 45% clause internally reported in [8] as cited by [9]. Contrary to the expectation of gradient pause duration, clause internal pauses were NOT found to be significantly shorter than pauses at clause boundaries or sentence boundaries (contra [10]). Only pauses at episode boundaries were significantly longer than pauses at all three other locations. This finding reflects the fact that the narrative analysed was characterized by very long pauses (>5.5 s) to mark major thematic shifts, following [11], [13]. These results, when taken together, suggest that pausing is a more reliable correlate of discourse, not syntax.

In terms of prosodic effects, pause duration was found to be inversely related to speech rate, as for English ([9]), but not affected by the prior phrase length (contra [1]).

However, these correlation analyses were based on only a subset of the data, and warrant further investigation, given the very small number of tokens. Another important limitation of this study to note is that these results are true of one speaker of one dialect and should not be taken as representative of the language as a whole, nor are the results meant to privilege this particular dialect in any way. Future research could consider more speakers of this and other dialects. Preliminary research on a related language shows higher consistency of pausing with clause boundaries, and the higher correlation between pausing and discourse particles in Nxaʔamxčín [2] vs. phrasal structure suggests that this link between pausing and discourse needs further examination. In terms of the implications for teaching, these results indicate that teachers can direct language students' attention to the function and location of pausing so the student can sound more like elders, a common goal in language revitalization [14].

Acknowledgments

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References

[1] Krivokapić, J. Prosodic planning: Effects of phrasal length and complexity on pause duration. Journal of Phonetics, 35(2), 162-179, 2007.

[2] Caldecott, M., and E. Czaykowska-Higgins. Prosodic phrasing in Nxaʔamxčín (Salish) declarative clauses. Canadian Acoustics, 40(3), 16–17, 2012.

[3] Caldecott, M. St'át'imcets intonation contours: A preliminary study. Canadian Journal of Linguistics/Revue canadienne de linguistique, 61(2), 119-155, 2016.

[4] Davis, H. Two types of discourse configurationality in languages of the Pacific Northwest. Handout presented at the Workshop on the Structure and Constituency of the Languages of the Americas 17, University of Chicago, 2012.

[5] Koch, K. Intonation and focus in Nlhe7kepmxcin (Thompson River Salish). Doctoral dissertation, University of British Columbia, 2008.

[6] Koch, K. A phonetic study of intonation and focus in Nłeʔkepmxcin. In Prosodic Categories: Production, Perception and Comprehension, (eds.), Frota, S., Prieto, P. and Elordieta, G., 111–144. Dordrecht: Springer, 2011.

[7] Alexander, C., K. Langergraber and J. Lyon. The Flooding of the Upper Bridge River Valley: St'át'imcets Narratives and an Artist's Exhibition. International Conference of Salish and Neighboring Languages 51, 1-17, 2016.

[8] Henderson, A., F. Goldman-Eisler and A. Skarbek. Sequential temporal patterns in spontaneous speech. Language and Speech, 9(4), 207 – 216, 1966.

[9] Goldman-Eisler, F. Psycholinguistics: Experiments in Spontaneous Speech, Academic Press, London, 1968.

[10] Cooper, W. E., and J. Paccia-Cooper. Syntax and speech (No. 3). Harvard University Press, 1980.

[11] Oliveira, M. Prosodic Features in Spontaneous Narratives. Doctoral Dissertation, Simon Fraser University, 2000.

[12] Benner, A. The prosody of SENĆOŦEN. Unpublished course paper, Department of Linguistics, University of Victoria, 2004.

[13] Smith, C. L. Topic transitions and durational prosody in reading aloud: production and modeling. Speech Communication, 42(3-4), 247-270, 2004.

[14] Bird, S. and S. Kell. The role of pronunciation in SENĆOŦEN language revitalization. Canadian Modern Language Review, 73(4,) 538-569, 2017.

PERCEIVING VISIBLE SPEECH ARTICULATIONS IN VIRTUAL REALITY

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1 Introduction

Advances in virtual reality (VR) and avatar technologies have created new platforms for face-to-face communication in which visual speech information is presented through avatars using simulated articulatory movements. These movements are typically generated in real time by algorithmic response to acoustic parameters. While the communicative experience in VR has become increasingly realistic, the visual speech articulations remain intentionally imperfect and focused on synchrony to avoid uncanny valley effects [1]. While considerable previous research has demonstrated that listeners can incorporate visual speech information produced by computer-simulated faces with precise and pre-programmed articulations [2], it is unknown whether perceivers can make use of such underspecified and at times misleading simulated visual cues to speech.

The current study investigates whether reliable segmental information can be extracted from visual speech algorithmically-generated through a popular VR platform. We focused on the platform's most consistent and easily perceived articulator movements: bilabial closure in consonants; and lip rounding, lip spreading, and jaw lowering in vowels (see Figure 1). We report on an experiment using a speech-in-noise task with audiovisual stimuli in two conditions (with articulator movement and without) to ask the following questions: 1) whether the visual information from an avatar improves identification of target words, and 2) whether that visual information improves categorization of the target segment.

1 Methods

19 native English speakers (ages 18-30) were recruited from the University of British Columbia Linguistics subject pool. An additional 10 non-native participants are excluded from analysis. Stimuli consisted of videos of an avatar saying simple sentences ("It's [TARGET]") captured in Facebook Spaces™ with Oculus Rift™ hardware. The stimuli were recorded using the in-app video capture feature which records both the avatar movement and the user's speech. Articulator movement was generated automatically through the app. For stimuli without lip movement, the Facebook Spaces microphone was disabled to prevent audio pick up and articulator movement. For all recordings, a simultaneous audio recording was made [Samson C03U mic] and dubbed into all videos using Kdenlive [3] and Final Cut Pro X [4].Consonant targets followed a 2x2x3 paradigm: articulator movement (with or without) x segment (bilabial or not), x minimal pair (3 pairs). Vowel targets followed a 2x3x2 paradigm: articulator movement (with or without) x segment ([i] [u] [ɑ]) x minimal triplet (2 triplets).

Figure 1: Samples of stimuli videos with targets [u], [i] and [ɑ].

Stimuli were presented on an iMac 2017 computer using OpenSesame 3.2.4 [5] and AKG K240 headphones in a sound-attenuated booth. Stimuli were randomized within a single block. The experiment consisted of 6 blocks (144 tokens in total), with breaks between blocks. A "babble" track was simultaneously presented though Audacity® [6] for the duration of the experiment. Participants were told to imagine that the avatar was giving answers to a crossword puzzle they were solving in a crowded cafe. After each video, participants were asked to type the word they had heard. The signal-to-noise ratio was calibrated empirically during a pilot study to achieve a 40% success rate for two native English speakers.

2 Results

One participant was excluded for not completing the task, leaving 18 subjects for data analysis. Our first question concerned whether visible articulator movement enhanced identification of the target word. Mean accuracy for the Articulator Movement condition was 8% higher than in the No Articulator Movement condition (35.7% vs. 27.6%, respectively) suggesting a small improvement with the addition of articulator information.

To answer our second question, we calculated accuracy rates for target consonant and vowel categorization. For consonants, accurate categorization was defined as responding with a bilabial-initial word when the target word was bilabial (e.g., initial /p/, /b/, or /m/ if the target word was *bit*) and responding with a non-bilabial initial segment when the target was not bilabial-initial (e.g., initial /h/ or /k/ when the target word was *hit*). For vowels, accurate

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categorization was defined as responding with a rounded vowel when the target word contained [u] (e.g., *pool*); a high front vowel (either [i] or [ɪ]) when the target word contained [i] (e.g., *peek*); and a low back vowel when the target word contain [ɑ] (e.g., *Paul*). The data were analyzed using linear mixed-effects models in R [7] with the lme4 [8] and lmerTest packages [9].

For the bilabial target words, participants showed a small *decrease* in categorization accuracy when visible articulator movement was available (-5%). In contrast, participants showed a 20% increase in accuracy for non-bilabial targets in the Articulator Movement condition, suggesting that participants became better at identifying something as not bilabial with the addition of visible articulatory information (see Figure 2). Results from a linear mixed effects model[1] show a significant interaction between Consonant and Articulatory movement (β = -0.25, SE = 0.05, t = -5.19, p < 0.001) such that participants were significantly better at categorizing non-bilabial target words when presented with visible articulator movement.

For vowel target words, participants showed small enhancement effects in the Articulator Movement condition for [u] and [ɑ] target words (4% and 5%, respectively), but a large increase in accuracy for [i] target words. A linear mixed effects model[2] revealed a significant effect of [i] (β = -0.18, SE = 0.06, t = -3.25, p < 0.01) such that participants were worse at categorizing [i] target words overall. In addition, a significant interaction between vowel [i] and Articulator Movement emerged (β= -0.24, SE = 0.06, t = -3.96, p < 0.001) supporting the observation that [i] categorization was enhanced by visible lip spreading.

Discussion and conclusions

The results suggest that even imperfect articulator movement from an avatar improves speech perception to some extent. However, the results also show that the imprecise articulatory movements were not as informative as those from a human source or a pre-programmed synthesized face. In particular, we observed that while a visible articulation of [i] significantly improved segmental categorization, visible articulation of [u] or [ɑ] did not. Perhaps most unintuitively, visible articulation did not improve accuracy of perception of bilabial-initial words, even though the lip movement was readily apparent. In contrast, articulatory movement enhanced categorization of *non*-bilabial sounds.

The avatar's simulated bilabial closure movement was very brief and lacked visible lip compression; the verisimilitude of this articulation was insufficient to aid perception and categorization of bilabials. Further fine-grained perceptual studies are needed to determine the balance of realism and abstraction to optimize perception, and thus successful and naturalistic avatar communication, without increasing signal lag.

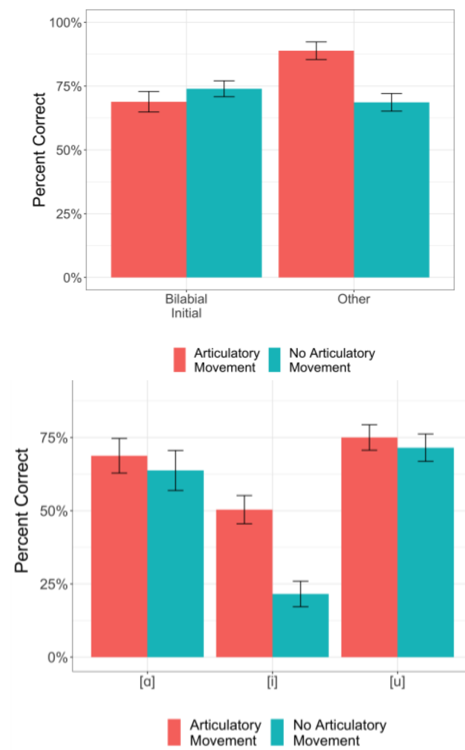

Figure 2: Mean accuracy for consonant (top) and vowel (bottom) target words for both conditions.

[1] *Accuracy ~ Consonant * Articulatory_movement + (1 + Consonant * Articulatory_Movement|Subject)*

[2] *Accuracy ~ Vowel * Articulatory_movement * + (1 + Vowel * Articulatory_Movement|Subject)*

Acknowledgments

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References

[1] Facebook for Developers - F8 2017 Keynote." Facebook for Developers. https://developers.facebook.com/videos/f8-2017/f8-2017-keynote/. Accessed October 28, 2018.

[2] Cohen, M. & Massaro, D. Synthesis of Visible Speech. *Beh. Res. Meth. Instr. & Comp. 22*(2), 260-263, 1990.

[3] Kdenlive. 18.04.1. May 11, 2018. J. Wood. USA

[4] Final Cut Pro X. 10.1.2. June 27, 2014. Apple Inc.. USA

[5] Mathôt, S., Schreij, D. & Theeuwes, J. OpenSesame: An open-source, graphical experiment builder for the social sciences. *Beh. Res. Meth.*, 44(2), 314-324, 2012.

[6] Audacity Team (2012) Audacity®. Version 2.0.0. Audio editor and recorder. http://audacityteam.org/. Accessed 26/04/2012.

[7] R Core Team. R: A language and environment for statistical computing. R Found. for Stat Comp, 2013. Vienna, Austria. http://www.R-project.org/.

[8] Bates, D., Maechler, M., Bolker, B. & Walker, S. lme4: Linear mixed-effects models using Eigen and S4. R package, version 1(7): 1-23, 2014.

[9] Kuznetsova, A., Brockhoff, P. B. & Christensen, R. H. lmerTest package: tests in linear mixed effects models. J. Stat. Soft. 82(13), 2017.

Single-Channel Vibrotactile Feedback for Voicing Enhancement in Trained and Untrained Perceivers

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1 Introduction

We evaluate the feasibility of using a single-channel vibrator to enhance the intelligibility of speech in acoustically noisy environments. Speech intelligibility can be enhanced by integrating information from other modalities, e.g., vision [1]. Nonetheless, there exists circumstances where shared visual attention is hard to establish, or in-person contact is infeasible (e.g., in a noisy collaborative environment such as an industrial shop floor). Previous research has established that direct manual touch can enhance speech intelligibility in noisy environments [2]. Touch is an ideal modality to address this problem.

Tactile aids have been used to enhance speech intelligibility through multichannel vibrotactile stimulation in clinical populations (including individuals who are hard of hearing) [3] [4] [5]. But little work has been done to address the feasibility of these devices for non-clinical populations, particularly using single-channel systems. Establishing the efficacy of a single-channel vibrotactile device is desirable because many people already own a single-channel vibrotactile device (such as a cellphone), and it could therefore be easily implemented in such everyday objects.

We informed the design of the system from a pilot study and a historically popular method of tactile speech enhancement, the Tadoma method, where listeners place their hands on a speaker's face and throat [6] [2]. Our device provides vibrotactile stimulation similar to the laryngeal vibrations felt in the Tadoma method by vibrating to the amplitude envelope of voiced speech. A pilot study with untrained perceivers was conducted to establish the ground truth that vibrotactile stimulation can enhance the intelligibility of speech as well as to inform the design of the system. Participants were tasked with identifying the content of speech in noise with and without the aid of a vibrator. Significant variance was attributable to vibration style ($F(2,48)=4.21$, $p=0.01$), as well as phonemic contrast ($F(2,48)=15.395$, $p=5.83\cdot10^{-6}$), but not vibrator placement. In the current study, a training phase was added (per results of [7]) and unpromising conditions from the pilot were eliminated. We demonstrate that vibrotactile feedback increases the accuracy scores of participants when discerning the content of speech in noise.

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2 Methods

2.1 Participants

20 participants were recruited from the University of British Columbia's Linguistics human subject pool. They were compensated with either course credit or $10 for their time.

2.2 Materials and Procedure

Stimuli

180 minimal pairs were utilized and randomized within testing trials. A subset of 120 words (60 per trial block) were used. Stimuli were recorded using the voices of male and female identifying English native-speakers with a DR40 TASCAM hand held linear PCM digital recorder. The volume between audio tokens was normalized before use in the experiment proper.

Procedure

Vibrations were administered through a Tectonic Elements Audio (TEAX12C02-8/RH) linear resonant acutator that was held between the index finger and thumb as to target the sensitive glabrous skin of the hands. The vibrotactile waveforms were procedurally generated from speech during the experiment. The vibrations were designed to mimic the laryngeal vibrations normally felt during voiced speech: they were only present on voicing, and the amplitude of the vibrations were coupled to the amplitude envelope of the speech. Auditory speech and noise were delivered through AKG over-the-ear headphones.

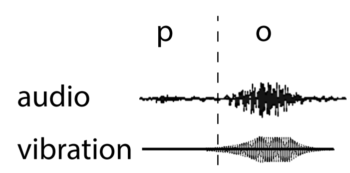

Figure 1: Above: example of how vibrations are generated from auditory speech. /p/ is unvoiced so there is no vibration present.

For each trial, we displayed a minimal pair on the computer screen accompanied by the audio of one of the words through the headphones (and optionally vibrations). Participants were then tasked with selecting the correct word. The experiment consisted of the following phases:

(1) *Training:* The training phase was intended to help participants get a feel for the speech-to-vibration mappings in an easy low-stakes environment. They were tasked with

making binary selections between minimal pairs over a low-volume babble track, with the aid of the vibrator. Each new word token was introduced with a 3 second visual countdown. If they chose incorrectly, they were prompted to try again. If they chose correctly, the task would continue for a total of 12 training trials until the next phase.

(2) *Calibration:* The calibration phase was similar to training phase, with removal of the countdown, vibrations, and correctness feedback. During calibration, we staircased the noise floor such that the participant's accuracy scores were just above chance (70% $\pm 5\%$).

(3) *Main phase:* During the main phase participants made binary selections between minimal pairs over a high-volume babble track. The main phase was blocked into a control block (where the participants held the vibrator but it did not provide vibrations) and treatment block (where the vibrator provided vibrations). Each block consisted of 60 minimal pairs, with pair order randomized, and block order counter-balanced between subjects.

3 Results

A 2-way repeated measures ANOVA was conducted to examine the effects of vibrations, and phonemic contrast on participant accuracy scores. There was a significant effect of vibration on accuracy scores at the $p<0.01$ level [F(1,19)=14.69 p=0.0012] and phonemic contrast on accuracy scores at the $p<0.01$ level [F(1,38)=14.9 $p=1.66 \cdot 10^{-5}$]. We found no significant interaction effect between phonemic contrast and vibrations. Participants performed better with the vibrator than without, with an 8.91% difference of means between the control and vibrotactile conditions.

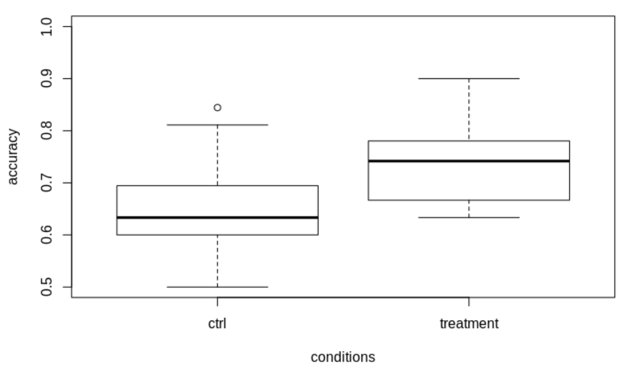

Figure 2: participant accuracy scores compared to control (no vibrations) and treatment (with vibrations)

4 Discussion

We demonstrated that single channel vibrotactile stimulation can effectively enhance the intelligibility of speech in noisy environments. The results show potential in integrating the system into an everyday object such as a cellphone. The underpinning cognitive mechanisms of vibrotactile enhancement remains unanswered for a follow up study. Accuracy scores could be enhanced because participants are using the vibrotactile signal to supplement linguistic content. However, in unstructured qualitative post-study interviews, many participants claimed that the vibrations helped more to discern when to pay attention to the relevant speech in noise. Thus, it is very likely that the vibrotactile signal could serve as an attentional aid, and need be only minimally motivated by the form of the speech signal.

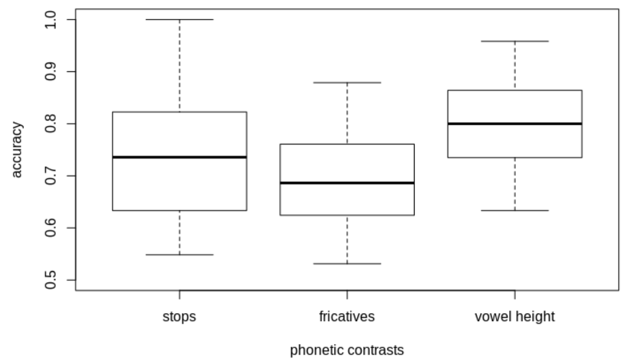

Figure 3: comparison of phonetic contrasts and participant accuracy scores when administering vibrotactile stimulation.

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References

[1] William H Sumby and Irwin Pollack. Visual contribution to speech intelligibility in noise. *The journal of the acoustical society of america*, 26(2):212–215, 1954.

[2] Bryan Gick, Kristín M Jóhannsdóttir, Diana Gibraiel, and Jeff Mühlbauer. Tactile enhancement of auditory and visual speech perception in untrained perceivers. *The Journal of the Acoustical Society of America*, 123(4):EL72–EL76, 2008.

[3] D Kimbrough Oller. Tactile aids for the hearing impaired: An overview. In *Seminars in Hearing*, volume 16, pages 289–295. Copyright© 1995 by Thieme Medical Publishers, Inc., 1995.

[4] Karyn L Galvin, Gina Mavrias, Alessandra Moore, Robert SC Cowan, Peter J Blamey, and Graeme M Clark. A comparison of tactaid ii and tactaid 7 use by adults with a profound hearing impairment. *Ear and hearing*, 20(6):471–482, 1999.

[5] Mark D Fletcher, Sean R Mills, and Tobias Goehring. Vibrotactile enhancement of speech intelligibility in multi-talker noise for simulated cochlear implant listening. *Trends in hearing*, 22:2331216518797838, 2018.

[6] Sophia Alcorn. The tadoma method. *Volta Rev*, 34(1932):195–198, 1932.

[7] Lynne E Bernstein, Silvio P Eberhardt, and Marilyn E Demorest. Single-channel vibrotactile supplements to visual perception of intonation and stress. *The Journal of the Acoustical Society of America*, 85(1):397–405, 1989.

TESTING SYMMETRY OF TEMPORAL WINDOW OF INTEGRATION IN VIBROTACTILE AND AUDITORY SPEECH INFORMATION ON PHONEME PERCEPTION

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1 Introduction

We show that temporal asynchronies between vibrotactile and auditory speech information follow a symmetrical distribution. Speech perception is more than a unimodal process: it requires concurrent integration of multiple sensory modalities. Auditory and visual modalities have been the main focus of many on multimodal speech perception studies, as seen in the well-known McGurk effect [1], where incongruent presentation of auditory and visual speech stimuli resulted in an integrated illusion. Multi-modal sensory signals don't need to be synchronous for effective integration [2]. Testing temporal constraints show that the illusion is still maintained when visual stimuli precedes audio stimuli for up to 180ms, but when audio stimuli precedes visual stimuli the window for integration shrinks to 60ms [2]. This explanation for asymmetry is resulting from a difference in signal speeds in the natural world: light travels faster than sound, so humans are more experienced in perceiving events where visual information is received before the audio information.

The tactile modality also contributes information for enhanced speech perception–syllables heard alongside puffs of air on the skin were more likely to be perceived as aspirated (e.g. hearing /ba/ as /pa/) [3]. A follow up study [4] demonstrated a temporal window of integration between -50ms and 200ms. This asymmetry can again be explained by a difference in relative signal speeds: sound travels faster than airflow, so integration has a larger window of opportunity in events where audio information precedes tactile information.

However, not all cross-modal integration can be explained with a difference in signal speed. Vibrotactile cues often accompany acoustic cues as experienced in the laryngeal vibrations felt during voiced speech, with little to no difference in relative signal speed (i.e. no concomitant perceptual asymmetry).

Through establishing temporal window for such vibrotactile devices, implications of cross-modal integration can be used in practical implementation to aid speech intelligibility in real time application.

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2 Methods

A pilot study [5] was conducted to establish effect of vibrotactile stimulation on speech intelligibility. Participants discriminated the content of speech in noise, while receiving vibrotactile stimuli through voice-coiled transducer. Device placement (neck vs hand), phonological contrast (fricatives, stops, vowel heights), and vibration styles were manipulated. Results showed greatest enhancement in speech perception when the amplitude of the vibrations were coupled to the amplitude envelope of voiced fricatives. The present study uses the ground truth established by the pilot as a framework to investigate the effects of temporal offsets on participant accuracy scores when discerning speech in noise.

2.1 Participants

We recruited 26 students from the University of British Columbia of normal-hearing, normal or corrected eye-vision, and have no previous experience with the tactile devices used in this experiment. All participants were compensated with course credit or $10 for their time.

2.2 Stimuli Delivery

Vibrations were administered through a Tectonic Element Audio (TEAX12C02-8/RH) linear resonant acutator (LRA) that was held between the index finger and thumb. The vibrotactile waveforms were procedurally generated from speech during the experiment–the vibrations were designed to mimic the laryngeal vibrations normally felt during voiced speech: they were only present on voicing, and the amplitude of the vibrations were coupled to the amplitude envelope of the speech. Auditory speech and noise were delivered through AKG over-the-ear headphones.

2.3 Stimuli

Each participant underwent 218 trials, where different phonemic contrasts and temporal offsets were randomly administered. Speech was recorded by a female identifying native speaker of English with a DR40 TASCAM hand held linear PCM digital recorder, audio file volumes were normalized before generating vibrations.

Phonemic contrasts: For consistency purposes and prevention of stimuli-related confounds, pre-vocalic voiced and unvoiced minimal pairs of fricatives (/va/ vs. /fa/, /za/ vs. /sa/) and stops (/pa/ vs /ba/) were used.There were 8 recordings for each minimal pair.

Temporal offsets: Temporal offsets of 0ms (synchronous), $\pm 50\ ms$, $\pm 100\ ms$, $\pm 200\ ms$, $\pm 300\ ms$ were administered. Offsets were given positive value when audio signals precede vibrotactile signals; and negative value when vibrotactile signals precede audio signals.

2.4 General Procedure

(1) Calibration Phase: Signal-to-noise ratio of target audio stimuli and background babble track were adjusted until above chance accuracy. Calibration responses were not recorded, except for volume and calibration accuracy.

(2) Testing Phase: Participants sat in front of computer monitor with over-the-ear headphones, while holding the vibrotactile device between their fingers. The target audio stimuli were played through the headphones, while the babble track in the background simulated a noisy environment. After audio and vibrotactile stimuli of different temporal offsets were presented,visual prompts would appear on the computer screen to elicit a correct selection in a forced-choice task Participants continued the process to the end of the experiment, response data was collected.

3 Results

Figure 1 compares the mean percentage of participant accuracy scores of temporal offsets overall, and in respect to phonemic contrasts (fricative vs stops). A 2-way ANOVA shows that there is no amount of the variation in accuracy scores can be attributable to the factor of temporal offset ($F_{(1,25)}$ = 0.0061, p = 0.94),however, there is significant variation for the factor of phonetic contrast ($F_{(1,25)}$ = 66.0102, p = $1.7704*10^{-8}$). Since no variance can be accounted for in terms of temporal offset, skewedness was not tested. The distribution of the overall curve is not skewed in any discernible direction, and is symmetrical around an unknown mean [6].

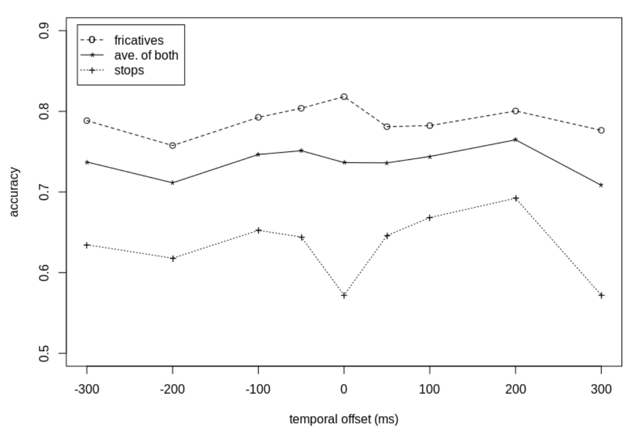

Figure 1: Mean average of participant accuracy scores

4 Discussion

Temporal offset did not effect accuracy scores as anticipated. However, there was a significant effect of phonemic contrasts on participant accuracy. Qualitative data from participants collected during an unstructured post-study interview reinforced the data that stops (pa/ba) were more difficult to perceive in general compared to the fricatives. There was no clear temporal window of integration between the vibrotactile feedback and audio signals. Possible reasons could be that instead of supplementing additional linguistic information–the vibrotactile feedback aided in directing the participant's attention to the audio signal. If that were the case, latency issues in the practical real-time application of such vibrotactile devices for speech intelligibility may not be of a big concern, as the perceiver could depend on the vibrations to guide their attention to what is being said.

Acknowledgments

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References

[1] Harry McGurk and John MacDonald. Hearing lips and seeing voices. *Nature*, 264(5588):746, 1976.

[2] Kevin G Munhall, P Gribble, L Sacco, and M Ward. Temporal constraints on the mcgurk effect. *Perception & psychophysics*, 58(3):351–362, 1996.

[3] Bryan Gick and Donald Derrick. Aero-tactile integration in speech perception. *Nature*, 462(7272):502, 2009.

[4] Bryan Gick, Yoko Ikegami, and Donald Derrick. The temporal window of audio-tactile integration in speech perception. *The Journal of the Acoustical Society of America*, 128(5):EL342–EL346, 2010.

[5] David Marino, Hannah Elbaggari, Tzu Hsu Chu, Bryan Gick, and Karon MacLean. Single-channel vibrotactile feedback for voicing enhancement in trained and untrained perceivers. *in press*, 2018.

[6] Weiwen Miao, Yulia R Gel, and Joseph L Gastwirth. A new test of symmetry about an unknown median. In *Random Walk, Sequential Analysis And Related Topics: A Festschrift in Honor of Yuan-Shih Chow*, pages 199–214. World Scientific, 2006.

[7] Katie Bicevskis, Donald Derrick, and Bryan Gick. Visual-tactile integration in speech perception: Evidence for modality neutral speech primitives. *The Journal of the Acoustical Society of America*, 140(5):3531–3539, 2016.

Cross-Linguistic Bracing: Analyzing Vertical Tongue Movement

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1 Introduction

The vocal tract has often been described as a tube that is shaped to produce different speech sounds [1]. The oral part of this tube is formed by the sides of the tongue making contact with the lateral teeth or palate. This tongue-palate contact has been described as "lateral bracing" [2]. Gick et al. [3] demonstrated that tongue bracing is maintained continually throughout running speech, hypothesizing that bracing is a key component of the basic posture underlying speech production. A limitation of their study, however, is that this kind of pervasive bracing has only been observed for a single language, English. If tongue bracing is fundamental to speech production, then it is expected to be a pan-linguistic phenomenon. The proposed work aims to test whether bracing occurs cross-linguistically.

A pilot study conducted by Cheng et al. [4] initially explored this question using ultrasound imaging; the authors hand-traced vertical movements of the sides of the tongue during continuous speech, and found preliminary support for the hypothesis that tongue bracing exists across six different languages. However, there were some methodological concerns that limited the interpretation of Cheng et al.'s [4] study, most notably that the movement of the centre of the tongue was not analyzed, and the hand measurements were so time-consuming that it was impractical to collect and analyze the large amount of reliable cross-linguistic data needed to test the hypothesis.

To address these limitations and test the cross-linguistic bracing hypothesis, we developed a new image processing-based technique that to improve the efficiency of data analysis. This approach allows us to examine data from a much larger number of speakers, and analyze both the center and the sides of the tongue.

This study aims to examine the hypothesis that tongue bracing is observed cross-linguistically for a significant sample of speakers of a number of different languages. The study tracks vertical positions of the tongue using automatic analysis of ultrasound imaging.

2 Method

Eight to ten native speakers of five different languages (English, Cantonese, Korean, Mandarin, and Spanish) were recruited to take part in the study. The languages were selected primarily because of their diverse phonetic systems and because of the availability of large numbers of speakers in Vancouver. The participants were asked to read aloud a translation of the passage "The North Wind and the Sun" [5] in their respective native languages. Each participant read the passage three times while a coronal section of their tongue was imaged using an ultrasound probe positioned under the posterior part of the chin and aimed roughly at the upper molars, a frame of the video collected is shown in Figure 1.

Figure 1: A frame of ultrasound video. The white curly line shows the coronal slice of the tongue.

In order to test for the presence of bracing, it is necessary to identify the most stable vertical location and its relative height for the sides and the centre of the tongue. Ultrasound data was analyzed using vertical movement tracking as follows. First, vertical movement of each of the three regions of interest (the left and right edges and the centre) of the tongue will be tracked over time throughout speech. For each of these three locations, the range of the stable area is defined as an error range above and below the most stable position. Figure 2 illustrates the tracking of one side of the tongue. The most stable position is defined as the horizontal row of pixels with the highest luminance value over the entire experiment indicating the location at which each tongue region spends the most time. The stable range is defined as ±10 percent of the total range of vertical movement of that tongue region (within speaker). The amount of time that the tongue stays above, within and below the stable position area were recorded within each region (hereafter referred to as proportion above (PA), proportion within (PW) and proportion below (PB)) to determine whether the stable area is relatively high or low in the total movement space.

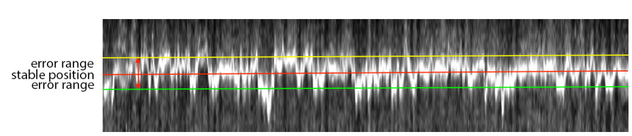

Figure 2: This kymograph illustrates the stable position (red line), error bars (red arrow), and the stable range (between the yellow line and the green line).

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3 Results

We determined PA, PW and PB by calculating the percentage of high white instances observed in each area. The white instances refer to the white pixels on the kymograph indicating tongue position. For example, PW of the left side is obtained by dividing the number of high white instances within the stable area by the total number of white instances. Figure 3 shows the value of PA, PW and PB in the three different regions of the tongue.

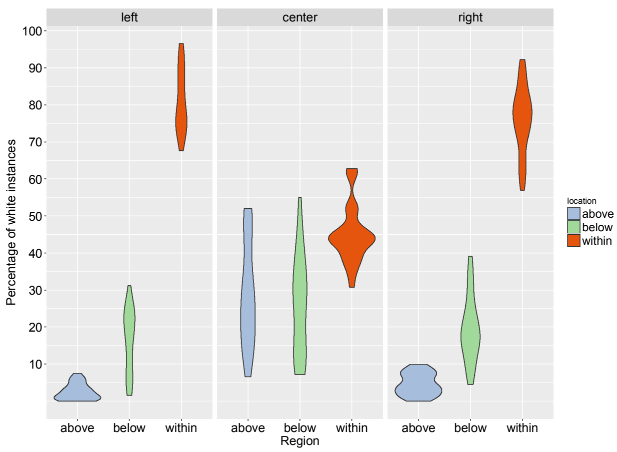

Figure 3: Percentage of white instances above, within and below the vertical stable area at different regions of the tongue.

The results showed that the left and right sides of the tongue had the highest PW. In other words, the sides of the tongue spent the least amount of time above and below the vertical stable area ($p<0.0001$), with PA having the least value. Also, very few amount of variations are observed of the PA value of sides compared to the PW and PB value. Further, the pattern of movement between the sides of the tongue was distinctly different from that of the center of the tongue. While the results showed that the center of the tongue also had the highest PW value over PA and PB ($p<0.0001$), there was no significant difference between PA and PB ($p=0.609$). This pattern was true across attested languages, as shown in Figure 4

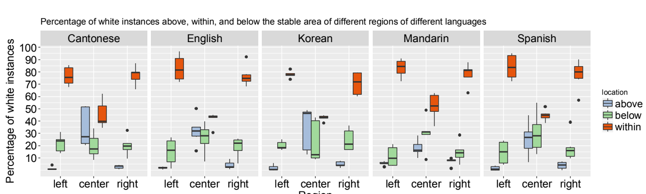

Figure 4: Value of PA, PW, PB at different regions of the tongue in different languages.

Figure 4 indicate that the sides of the tongue has very small PA value, slightly higher PB value, and the highest PW value for each individual language. Two different patterns of the vertical position where the center of the tongue stays at are presented in Figure 3. For Mandarin and Spanish speakers, their center of the tongue has a higher PW value than PB, with PA having the least value. However, for the other languages, speakers has higher PW than PA, with PB having the least value.

While the sides of the tongue behave the same way across different languages, some individual variation was seen in the amount of the time spent below the stable area. Within each language, for some speakers, the left side of the tongue stays in the below area more than their right side, while others display the same pattern but on the right.

4 Discussion

The results indicate that during speech production, the sides of the tongue (1) stay mainly within the vertical stable area (2) stay below the vertical stable area some of the time, and (3) stay above the vertical stable area occasionally. This implies that the sides of tongue positioned within a narrow area at a relatively high space in the mouth most of the time. This corresponds to the high percentage of time spent within the vertical stable position (where the sides of the tongue are during bracing) and the very low percentage of time spent above the stable position. We interpret these observations as indicating the bracing gesture of the tongue during speech and cross-linguistically.

The release of the bracing gesture was also examined. Release is indicated by observing the sides of the tongue which sometimes remain below the stable area. This occurs during the production of lateral sounds and low retracted vowel across different languages. These findings give support to the results of Cheng et al.'s [4] study and Gick et al.'s [3] study.

The finding that speakers tend to use one side more than the other during release suggests a high system tolerance for asymmetry. Further research could examine this asymmetrical pattern of lateral release in bracing.

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References

[1] Ladefoged, P., & Johnson, K. (2014). A course in phonetics. Nelson Education.

[2] Stone, M. (1991). Toward a model of three-dimensional tongue movement. Journal of Phonetics, 19, 309–320.

[3] Gick, B., Allen, B., Roewer-Després, F., & Stavness, I. (2017). Speaking tongues are actively braced. Journal of Speech, Language, and Hearing Research, 60(3), 494-506.

[4] Cheng, H. Y., Murdoch, B. E., Goozee, J. V., & Scott, D. (2007). Electropalatographic assessment of tongue-to-palate contact patterns and variability in children, adolescents, and adults. JSLHR , 50(2), 375-392.

[5] International Phonetic Association (1999). Handbook of the International Phonetic Association: A guide to the use of the International Phonetic Alphabet: Cambridge U. Pr.

Coarticulation Of Speech And Smile Movements

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1 Introduction

Facial expressions and speech movements can impose conflicting demands on speech articulators. For example, the bilabial closure for stop consonants /p/, /b/, and /m/ compete with the lip spreading and opening associated with smiling and laughing. Anecdotal evidence suggests this conflict may at least in some cases resolve as labiodental stop variants [1], though this discussion has been controversial (see [2], p. 18). Instances of conflict such as this can be useful in determining underlying control mechanisms in speech [3, 4, 5].

A simple model of coarticulation – one of unmediated superposition of muscle activations [6] – predicts that the outcome of this conflict may be determined by summing opposing forces due to competing muscle activations. In such a model, varying degrees of smile and varying degrees of closure force (e.g., for different stop consonants) should be expected to produce distinct outputs. Closures for /m/, /b/ and /p/ are known to vary (increasingly) in both intraoral pressure [7] and muscle force [8].

For the present paper, a pilot experiment is presented in which different bilabial stops are produced simultaneously with varying degrees of smile. Given the variation in muscle activation between the three stops and different degrees of smile, we predict that coarticulatory interactions in smiled speech will result in bilabials with lower activation such as /m/ being labiodentalized more often than bilabials with greater activation. Similarly, we predict that degrees of labiodentalization will vary depending on the strength of smile articulation. Finally, sequences with bilabials preceding or following a phonemic labiodental will benefit from the adjacent activation and have the highest chance of becoming labiodentalized.

2 Methods

Two native English speakers were recruited as participants in this study. Participants were seated in an experiment chair with a mirror positioned to their left to capture a side profile of the face and asked to read aloud 31 different sentences under three different facial conditions – neutral, smiling, and laughing. Sentences were presented in increments of five seconds; after every ten sentences, fifteen-second breaks were provided to reduce participants' facial muscle fatigue. Although absent from the present analysis, muscle amplitude of utterances under all three smile conditions was measured using surface electromyography electrodes placed on each participant's upper lip (in the vicinity of orbicularis oris) and cheek (in the vicinity of zygomaticus major) to be analyzed in future research. Each participant was asked to read the list of sentences once under each of the three smile conditions. The sentence list was structured such that five sentences per target sound was used, each containing a word where the bilabial consonant /b/, /p/, and /m/ was in a post-vocalic, word-final position.

Five sentences with target words containing the labiodental fricative /f/ and the bilabial glide /w/ in a post-vocalic, word-final position were also included. To examine the coarticulatory effects of adjacent bilabial/labiodental segments, five sentences with target words containing this series (ex. /bv/, /pf/) were added to the sentence list. Target words in all sentences were controlled for frequency and stress and rounded vowels preceding target bilabial phonemes were avoided to prevent contamination of data. Sentences were shown to participants in randomized order and the block of 31 sentences read under three conditions was repeated twice resulting in a total of 186 sentences read aloud.

Figure 1: Production of /p/ under neutral, smile and laugh (clockwise from upper left) conditions.

Video data were coded categorically noting whether a sound (b/p/m/f/v/w) was labiodentalized (yes/no) and under which smile condition (neutral/smile/laugh). Chi-squared tests were used to determine which facial condition most often accompanied labiodentalization and which target sounds were most commonly labiodentalized. Variables were aggregated into two contingency tables for yes/no vs. state and yes/no vs. consonant and chi-squared contingency tests were performed on each table using the Python scipy.stats package.

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3 Results

As Figure 2 illustrates, frequency of labiodentalization vary significantly depending on the different facial contexts the phoneme was produced. As predicted, the laugh condition where stress on articulators was greatest generated the highest frequency of labialized bilabial sounds. The chi-square value for this table was 28.93 ($p < .0001$).

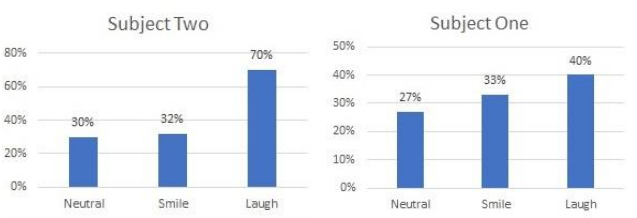

Figure 2: Instances of labiodentalization under varying conditions. Results indicate that the laugh condition exhibited the highest frequency of labiodentalization.

To test whether bilabial sounds with higher levels of muscle activation are less likely to be labiodentalized, another chi-squared test was run examining the labiodentalization variation between the six target phonemes /b/, /p/, /m/, /f/, /v/, and /w/. As figure 3 shows, labiodentalization for /p/ proved to be drastically lower than that of /b/ or /m/.

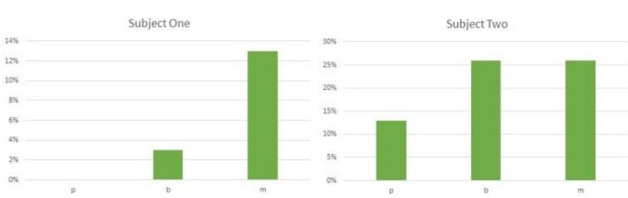

Figure 3: Instances of labialized phonemes for different sounds for subject one and two

4 Discussion

Results from this pilot study indicate that (1) labiodentalization of bilabial stops varies depending on level of conflicting demand from degree of smile and (2) the degree of intraoral pressure of the target sound negatively)influences the likelihood of the sound becoming labiodentalized. While labiodentalization was most likely to occur during the laughing condition where demands on articulators was greatest, there exists substantial variation with percentages of conventional articulation for consonants in neutral and smile conditions to exceed likelihood of labiodentalization. Also as predicted, stop sounds adjacent to labiodental are most likely to be labiodentalized.

5 Conclusion

The present study tested the prediction that bilabial stop consonants such as /m/ with lower intra-oral pressure, and hence lower muscle activation, are more frequently labiodentalized than bilabials with higher activation levels such as /p/ when produced while smiling or laughing. In addition, varying degrees of smile or laugh (and hence degrees of muscle activation) results in increased instances of labiodentalization.

This pilot study adds to the literature on articulatory conflict revealing embodied coarticulatory mechanisms. Future studies will replicate this experiment with a larger number of participants in addition to measuring degrees of closure during sentence production to quantify degrees of labialized bilabial sounds, and will include electromyographic muscle activation results.

Acknowledgments

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References

[1] Wells, J. (2012, March 6). John Wells's phonetic blog: uɱ... Retrieved November 12, 2018, from http://phonetic-blog.blogspot.com/2012/03/u.html

[2] Ladefoged, P., & Maddieson, I. (1995). *The sounds of the world's languages*. Oxford, UK;Cambridge, Mass. USA;: Blackwell.

[3] Gick, B. & Wilson, I. Excrescent schwa and vowel laxing: Cross-linguistic responses to conflicting articulatory targets. In L. Goldstein, D. H. Whalen & C. T. Best (eds.) *Papers in Laboratory Phonology VIII: Varieties of Phonological Competence.* Berlin, New York: Mouton de Gruyter. 635-660. 2006.

[4] Derrick, D. & Gick, B. Accommodation of end-state comfort reveals subphonemic planning in speech. *Phonetica.* 71, 183-200. 2014.

[5] Derrick, D., Stavness, I. & Gick, B. Three speech sounds, one motor action: evidence for speech-motor disparity from English flap production. *J. Acoust. Soc. Am.* 137, 1493-1502. 2015.

[6] Gick, B., Stavness, I. & Chiu, C. Coarticulation in a whole event model of speech production. *PoMA* 060207, 19, 5. 2013.

[7] Lubker, J. F., & Parris, P. J. (1970). Simultaneous Measurements of Intraoral Pressure, Force of Labial Contact, and Labial Electromyographic Activity during Production of the Stop Consonant Cognates /p/ and /b/. *J. Ac. Soc. Am.*, *47*(2B), 625–633.

[8] Gick, B., Francis, N., Chiu, C., Stavness, I. & Fels, S. Producing whole speech events: differential facial stiffness across the labial stops. *J. Acoust. Soc. Am.* 131. 3345. 2012.

TONGUE BRACING UNDER BITE BLOCK PERTURBATION

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1 Introduction

Tongue bracing against the teeth or palate is a pervasive posture maintained continually during normal speech [1]. However, it is unknown whether this bracing is truly necessary for speech, or it is simply a convenient resting place for the sides of the tongue while the jaw is in a relatively high position during speech. The present study aims to test whether the tongue adapts and maintains its bracing position to provide a single, postural parametric mechanism even when the jaw is held open using a bite block. Speech sounds have been shown to adapt quickly but imperfectly under bite block perturbation [2] [3]. When bite blocks translate the jaw (and thereby the tongue) downward, substantial distance is created between the tongue and the hard palate/upper molars, such that bracing would require active upward movement of the sides of the tongue.

Results of an experiment are presented in which native English-speaking participants read aloud a passage under two bite block conditions. Intraoral video results are reported, measuring positions of the lateral tongue for indications of stable bracing postures. In addition, a biomechanical simulation was conducted to help clarify the role of active muscle engagement under bite block conditions. Implications of these findings will be discussed for models of speech production.

2 Bite block experiment

2.1 Methods

In the present study, video footage was recorded while six native English-speaking participants read aloud an approximately one-minute-long passage under two bite block conditions. The passage was designed with no labial sounds in order to avoid the lips obstructing the camera view. 5mm and 10mm bite blocks were constructed using wooden tongue depressors, and a small LED light was attached to each bite block to illuminate the oral cavity.

Each participant was seated with the head stabilized. Two bite blocks were placed in the mouth, with one on each side held by the top and bottom back molars. A camera (Sony Cyber-shot DSC-RX100) was positioned directly in front of the mouth, and was manually focused on the upper back molars. For each trial, the participant was first asked to read the passage twice with 5mm bite blocks, then twice again with 10mm bite blocks. For each reading, the video recording was started a few seconds before the participant began in order to get footage of the rest position.

For each participant, the token with better imaging quality was selected for each condition, and the 30fps video was converted into an image sequence. We then used the software ImageJ [4] to produce kymographs for the left, right, and center of the tongue (see Figure 1). Each kymograph represents the activity over time through one slice of the video. For the middle of the tongue, the slice was taken between the central incisors; for each side of the tongue, the slice was taken at the back molar.

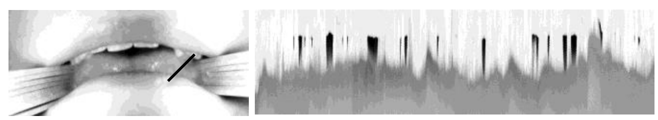

Figure 1: A frame of the video (left), with the black line indicating the location and angle of the slice used to produce the kymograph (right). Each column of pixels corresponds to one frame of the video.

Each kymograph was then turned into non-grayscale black-and-white: light areas correspond to the tongue and teeth, and dark areas correspond to the back of the oral cavity, which is visible when there is no contact between the tongue and palate/teeth. Then, the beginning and end of the kymograph was cropped so that the remaining portion corresponds to active speech. Lastly, a Python script was used to count the number of black pixels in each column of the kymograph, which corresponds to the amount of release from bracing position in one frame of the video. The number of columns that do not contain black pixels corresponds to the duration of contact.

2.2 Results

The amount of time during which the tongue was in contact with the upper teeth/palate was converted into percentages (see Figure 2). The results show that the sides of the tongue are almost always in contact with the upper teeth/palate across all speakers regardless of the size of the bite block. However, the center of the tongue does not adopt any such pervasive and parametric posture.

Further, it can be observed that the lateral bracing posture can be interrupted for the production of lateral liquids and some low vowels. Figure 3 shows the sides of the tongue moving away from the braced posture when producing some instances of the lateral liquid [l] and the low vowels [a] and [ɑ].

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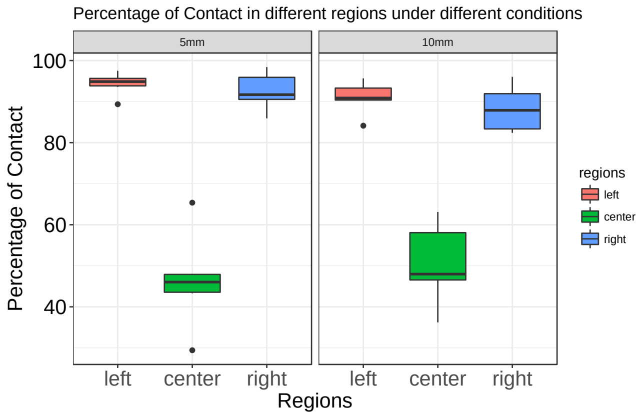

Figure 2: Duration of contact with the upper teeth/palate for different regions of the tongue.

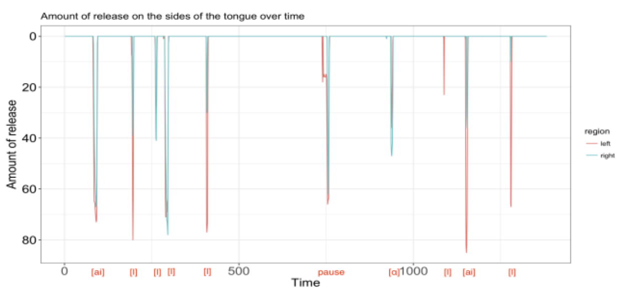

Figure 3: Tracking of the vertical movement of one side of the tongue for one participant. The dips indicate movement away from the bracing posture.

2.3 Experiment discussion

The finding that lateral bracing is maintained during speech production under perturbation from bite blocks of different sizes indicates that speakers use bracing as a parametric, intentional, and pervasive mechanism in speech production, in line with Gick et al. (2017). We conducted a biomechanical simulation to further support this point.

3 Biomechanical simulation

Muscle-driven forward-dynamic simulations were employed to assess the minimal degree of muscle activation necessary to achieve bracing during natural speech (control condition) and during speech with downward jaw and tongue translation (bite-block conditions). The present analysis uses a 3D finite-element model of the tongue developed by Buchaillard, Perrier, and Payan (2009) [5], with physical parameters mirroring those of Gick et al., (2017). We observed that the minimally-sufficient muscle activation to achieve bracing in natural speech required substantial increases in order to obtain bilateral contact under bite block conditions. Table 1 provides the degree of muscle activation for bilateral openers of the jaw and the minimally-sufficient muscle activation to achieve contact in both conditions. Figure 4 provides illustrations of the simulation using coronal sections from a posterior perspective. Visible artifacts in the tongue illustrations result from sectioning.

Table 1: Minimum activation for contact in each condition.

	JAWO	GGP	MH	VERT	SL
Control	4%	20%	20%	30%	30%
Bite Block	6%	30%	40%	30%	60%

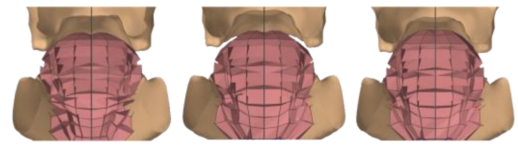

Figure 4: Bilateral contact in control (left), no contact without increased muscle activation in BB condition (center), and contact following minimally-increased muscle activation (right).

4 Discussion

Although lateral bracing under bite block conditions requires significant effort to raise the tongue, speakers still consistently maintain a braced posture with both 5mm and 10mm bite blocks. Furthermore, although lateral bracing is not required for the production of lateral consonants and low vowels, bracing is often maintained through these speech sounds, which means that bracing is likely the default parameter, while release occurs only when necessary.

5 Conclusion

The present study shows that lateral bracing is actively maintained under different degrees of jaw perturbation, suggesting that bracing is a crucial component of speech production. In view of this, it is worth reconsidering current conventions of representing the tongue, which are heavily biased towards the midsagittal plane, and therefore overlook phenomena occurring off-midline. Considering that bracing is indeed a parametric speech posture that continually underlies speech production, future work should consider its implications more broadly for areas such as phonetics, phonology, sound change, clinical practice, and so on.

Acknowledgments

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References

[1] B. Gick, B. Allen, F. Roewer-Després, and I. Stavness. Speaking tongues are actively braced. *JSLHR*, 60:494, 2017.

[2] T. Gay, B. Lindblom, and J. Lubker. Production of bite-block vowels: acoustic equivalence by selective compensation. *JASA*, 69:802, 1981.

[3] J. E. Flege, S. G. Fletcher, and A. Homiedan. Compensating for a bite block in /s/ and /t/ production: palatographic, acoustic, and perceptual data. *JASA*, 83:212, 1988.

[4] C. A. Schneider, W. S. Rasband, and K. W. Eliceiri. NIH Image to ImageJ: 25 years of image analysis, *Nature methods*, 9(7):671-5, 2012.

[5] S. Buchaillard, P. Perrier, and Y. Payan. A biomechanical model of cardinal vowel production: muscle activations and the impact of gravity on tongue positioning. *JASA*, 126(4):2033–51, 2009.

LATERAL BIAS IN LINGUAL BRACING DURING SPEECH

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1 Introduction

Human bodies exhibit lateral bias between many laterally symmetrical body parts (e.g, hands, feet, eyes, and ears). This bias is thought to increase the efficiency of behaviour and functionality of a system: e.g., laterally biased eyes produce depth perception rather than double vision [1]. Here we examine lateral biases observed in the tongue during speech, a grossly symmetrical structure at a muscular level [2]. During speech, the tongue is bilaterally braced against the back teeth and, for some sounds, the hard palate [3-6]. This bracing assists in the mechanics of certain tongue movements [7] and in the production of medial speech sounds, but is interrupted for the production of some laterals and occasional low vowels [5]. Some previous evidence suggests the movement away from the braced posture may be produced by lowering one side of the tongue first and that the leading side is consistent within speaker [5, 8].

We report observations of lateral bias in 6 English speakers, describe its relationship to other lateral biases of those speakers, and suggest possible implications for origins of this bias. If the larger population shows no overall bias (i.e., neither side is represented more than the other), this bias could emerge out of relatively stochastic developmental processes, such as dentition and behavioural optimization during feeding [9]. In such cases, a lateral preference would emerge depending on the environment in which bracing develops. If, however, there appears to be a population-level bias (most speakers prefer one side over the other), this process would instead develop with cortical modulation in much the same way that handedness is thought to arise [10].

2 Methods

2.1 Materials and Procedures

Video footage was recorded for 6 native English speakers using a video camera (Sony Cyber-shot DSC-RX100) held by an instrument arm attached to the chair where the participant was seated. Each participant read aloud a one-minute-long English passage while biting on two 5mm bite blocks (stacked narrow wooden tongue depressors). The passage was designed to minimize labial sounds to prevent lip closure from obstructing the camera view. The bite blocks kept the mouth open throughout reading, allowing a clear image of tongue movements. An LED light attached to each bite block illuminated the oral cavity.

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Participants were seated with their head stabilized against a headrest with the bite block positioned between the top and bottom molars on each side of the mouth. The passage was read twice. To obtain a baseline resting position for each participant's tongue, the video recording began a few seconds prior to the reading.

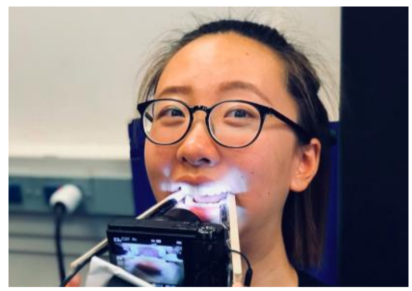

Figure 1: Experimental setup showing participant seated and fitted with bilateral bite block.

2.2 Analysis

Each video recording was digitized into kymographic image sequences via ImageJ [11]. Images were stacked and analyzed in orthogonal views, and kymographs were taken of the center, left and right sides of the tongue (See Figure 2). Each kymograph shows the activity through one slice of the video over time. The center intersect line for the kymograph was positioned between the front teeth; the left and right intersect lines were positioned at the back molar.

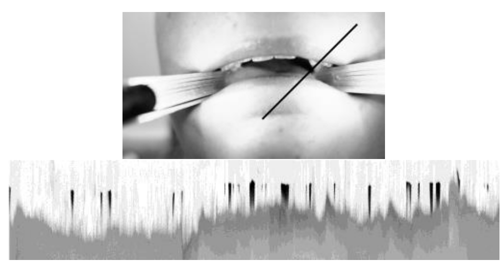

Figure 2. A frame of the video (left), with the black line indicating the location and angle of the slice used produce the kymograph (right). Each column of pixels corresponds to one frame of the video.

Each kymograph was then turned into a black-and-white image, with white areas corresponding to the tongue and teeth, and black areas corresponding to the open oral cavity, indicating lack of contact between the tongue and teeth. The kymograph was then cropped to contain only active speech. Lastly, a Python script was used to count the number of black pixels in each column of the kymograph (corresponding to the distance of the release from the braced position in one frame of the original video). The movement that the sides of the tongue made away from the braced posture has also been referred to as release [5]. The magnitude of release of both sides of the tongue is determined by the area of black regions shown in the kymograph. The black regions indicate no contact between one side of the tongue and the upper teeth, and the vertical magnitude of the black region shows the distance from the side of the tongue and the teeth. Further, the width of the black region presents the duration of the release. Hence, a larger black region illustrates a more significant movement away from the braced posture.

3 Results

Figure 3 shows the total amount of release for each side of the tongue for each speaker.

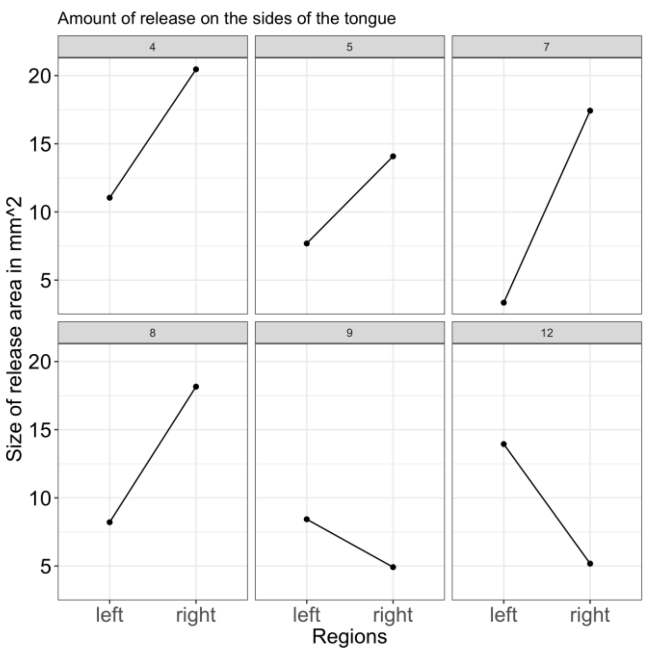

Figure 3: The amount of release of both sides of the tongue for each speaker. Each block shows the result of one participant, Higher values indicate larger black pixel regions on a given side.

The results indicate that one side of the tongue has a larger movement during release than the other side for all participants. Specifically, participants 4, 5, 7, and 8 show greater release for the right side of the tongue, whereas participants 9 and 12 show greater release for the left side. For the two participants with a left side bias, one of them reports being always right-handed while the other reports being left-handed. The rest of participants exhibiting right side biases are all right handed. However, the current sample size is too small to test for a correlation between the lateral bias in the tongue and handedness across participants.

4 Discussion and conclusions

Our results indicate that speakers exhibit a lateral bias in the tongue during speech. Participants demonstrated consistent lateral preferences in the tongue when producing lateral liquids and some low vowels. During bite block-braced speech, which exaggerates the movements of the tongue by increasing the vertical distance between the tongue and the palate/teeth, participants showed both a greater number of instances of tongue release as well as a greater magnitude of release for one side of the tongue than another. Given the small number of participants in the current study, it remains unclear whether this bias correlates with handedness. However, the right side is favored for use in 4 out of 6 cases and it is certainly interesting that the directional bias does match for 5 of our 6 speakers. If future research finds that this tendency continues to indicate a population-level bias matching handedness, this will indicate that the emergence of this bias is likely influenced by cortical processes during development. Further research will test whether such a population-level bias exists, so as to determine whether this bias results from similar processes as handedness.

Acknowledgments

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References

[1] McBeath, M. K., & Sugar, T. G. 2005. Natural selection of asymmetric traits operates at multiple levels. *Behav. & Brain Sci.*, *28*:04.

[2] Sanders, I., & Mu, L. 2013. A three-dimensional atlas of human tongue muscles. *Anat. Record*, *296*:7, 1102–1114.

[3] Gibbon, F. E., Lee, A., & Yuen, I. 2010. Tongue-palate contact during selected vowels in normal speech. *Cleft Pal.-Craniofac. J.*, *47*:4, 405–412.

[4] Lee, A., Gibbon, F. E., & Oebels, J. 2015. Lateral bracing of the tongue during the onset phase of alveolar stops: An EPG study. *Clin. Ling. & Phon.*, *29*:3, 236–245.

[5] Gick, B., Allen, B., Roewer-Després, F., & Stavness, I. 2017. Speaking tongues are actively braced. *JSLHR*, *60*:3, 494.

[6] Narayanan, S.S., Alwan, A.A. and Haker, K. 1997. Toward articulatory-acoustic models for liquid approximants based on MRI and EPG data. Part I. The laterals. *JASA*, *101*:2, pp.1064-1077.

[7] Stone, M. 1991. Toward a model of 3-dimensional tongue movement. *J. Phon.*, *19*(3-4), pp. 309-320.

[8] Chen, L., Schellenberg, M., & Gick, B. 2017. Cross-linguistic bracing: A lingual ultrasound study of six languages. *Can. Acoust.*, *45*(3), 186-187.

[9] Hiiemae, K. M., & Palmer, J. B. 2003. Tongue movements in feeding and speech. *Crit. Rev. Oral Biol. & Med.*, *14*(6), 413–429.

[10] Strauss, E., & Wada, J. 1983. Lateral preferences and cerebral speech dominance. *Cortex*, *19*(2), 165–177.

[11] Schneider, C. A.; Rasband, W. S. & Eliceiri, K. W. 2012. NIH Image to ImageJ: 25 years of image analysis. *Nature Meth.* **9(7)**: 671-675, PMID 22930834 (on Google Scholar).

SOUND-STREAM II: TOWARDS REAL-TIME GESTURE-CONTROLLED ARTICULATORY SOUND SYNTHESIS

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1 Background and motivation

Articulatory speech synthesis is utmost important for understanding the mechanism of human speech production. It encompasses the production of speech sounds using an artificial vocal tract model and simulating the movements of the speech articulators like tongue, lips, velum etc. However, despite having considerable significance in research and learning purposes, there is a dearth of intuitive user interfaces to effectively control the articulatory parameters based on simultaneous variation of speech articulators.

This is because of the level of complexity of the vocal tract articulators, that participate in speech production process. Vocal tract comprises of several organs, carefully controlled by the muscles. One of the key principles involved in articulatory synthesis lies in the simultaneous activation of these muscles to perform a multidimensional control of various parts of the vocal tract. Such movement occurs in an extremely interdependent manner, due to the intermingling of muscles.

2 Previous Works

The prevalent user interfaces targeting such movements like Pink Trombone [1], VT Demo [2] etc utilize simple mouse-based kinematic control of midsagittal sliced tongue, lips, hard palate and velum. These controllers allow the user to manipulate individual parts of the tract - one at a time, to synthesize the vocal sounds. Furthermore, these changes occur in some predefined trajectories which are less intuitive and difficult to relate to the slider changes triggered by the user. There is a lack of user flexibility, since a user can achieve only one particular shape among a number of pre-defined tongue shapes, corresponding to changes in slider values. Furthermore, it essentially enables user to explore the effect of only one articulatory parameter or shape/deformation of one part of the tongue for production of vocal sound. The other parts of the same articulator or different articulators are assumed to be fixed.

Therefore, this kind of control becomes highly unrealistic when compared to the actual articulatory speech production process. In particular, the tongue is a highly deformable, muscular hydrostat organ with infinite degrees of freedom, equipped with eleven muscles (extrinsic and intrinsic) controlling its shape and position. Kinematic control of a handful of points on the tongue surface [3] ignores the practical biomechanical constraints and the neuro-muscular pathway behind speech. Hence, more research needs to be directed towards user-interface facilitating the control and manipulation of the tract contour including tongue. Besides, most of the interfaces allow mere independent controls of various parts, which means control of one part of the articulator do not reflect any changes in the other parts or do not provide any feedback to the user for the variations in other interrelated parts. However, in reality, our muscles and articulators are intimately interleaved and have biomechanical constraints, because of which, movement in one part of an articulator renders changes in other parts as well. To this end, we develop our SOUND STREAM Interface trying to develop a hand-manipulated force-based realistic tongue-control strategy for sound production.

3 Overview of the proposed methodology

We present an interface involving four degrees-of-freedom (DOF) mechanical control of a two dimensional, mid-sagittal tongue through a biomechanical toolkit called ArtiSynth [4] and a sound synthesis engine called JASS [5] towards articulatory sound synthesis. As a demonstration of the project, the user will learn to produce a range of JASS vocal sounds, by varying the shape and position of the ArtiSynth tongue in 2D space through a set of four force-based sensors. In other words, the user will be able to physically play around with these four sensors, thereby virtually controlling the magnitude of four selected muscle excitations of the tongue to vary articulatory structure. This variation is computed in terms of 'Area Functions' in ArtiSynth environment and communicated to the JASS based audio-synthesizer coupled with two-mass glottal excitation model to complete this end-to-end gesture-to-sound mapping.

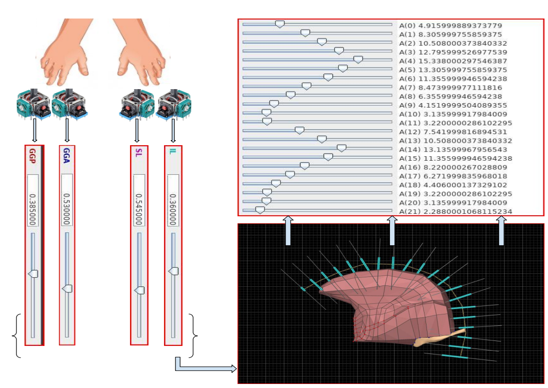

Figure 1: The proposed hand gesture-to-sound control pathway

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4 System Design

Our hardware interface consists of four mini-joystick force sensors mounted on a fixed platform. These sensors are potentiometer based force sensitive resistors that measure the applied force. The finger pressure exerted on each of the joysticks result in changes of resistances connected as a part of each voltage divider. Consequently, the analog input of Arduino microcontroller measures the output voltages, which are then translated to the tongue muscle excitations. The software interface consists of communication protocols between Arduino, ArtiSynth and JASS.

5 Detailed Mechanism

The proposed real-time gesture controlled sound synthesizer, through biomechanically-driven articulatory pathway, has three main phases (See Fig. 1), as discussed below:

5.1 Gesture-to-muscle activations

The first step is force-activated tongue muscle control, where we essentially replace the high-dimensional neural control of muscles by low dimensional hand gesture based tongue muscle manipulation. Here, we follow a simplistic force-to-muscle mapping strategy, where the tongue muscle activation ranging from 0 to 1, varies proportionally with the force exerted by the fingers.

5.2 Muscle-to-movement

We particularly select two intrinsic (Inferior and superior longitudinal) and two extrinsic muscle groups (Anterior and posterior genioglossus) to be controlled by the ambidextrous hand gestures. The longitudinal muscles are responsible for tongue retraction, making it short and thick. On the other hand, the genioglossus plays a major role in tongue protrusions and moving the tongue tip back and down. So variation of these muscle group excitations have significant effect on tongue shape and position.

The established forward biomechanical pathway in ArtiSynth [4] allows conversion of muscle excitations to resultant movements. We utilized this to get tongue shape and position changes from the real-time variation of selected muscle activations. Next, we constructed a series of beams around the tongue, with 22 fixed markers set at regular intervals along the vocal tract surface, following [6], as shown in Fig. 2. We further computed the distance between the tongue surface (varying with muscle activation changes) and these markers and derived the effective cross sectional area function for feeding it into the articulatory audio synthesizer.

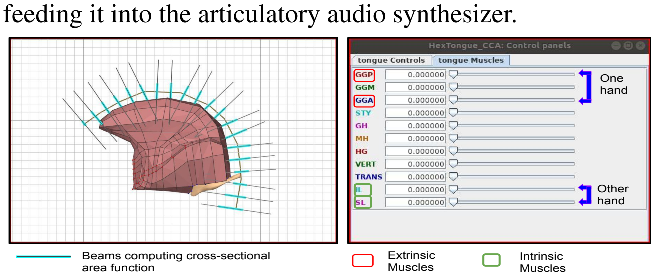

Figure 2: ArtiSynth Tongue Control

5.3 Movement-to-Sound output

The array of area functional values are sent in real-time to the Java Audio Synthesis System (JASS) which considers the vocal tract as an acoustic tube with its shape changing accordingly with the area functions. Glottal excitation pulse was generated according to the Rosenberg's model and coupled to discretized acoustic equations in the vocal tract. The acoustic wave propagation was simulated by numerically integrating the linearized 1D Navier-Stokes pressure-velocity PDE in time and space on a non-uniform grid. The synthesis mechanism involved excitations acting as source placed in the tube and sound propagation being simulated by approximating the pressure-velocity wave equations.

6 Discussions and Conclusions

In this work, we explored a low-dimensional subspace of the high dimensional neuro-muscular control of tongue muscles, towards articulatory vocal sound synthesis. Using this interface, the user can use his/her fingers to play around with the muscle activations, to achieve real-time changes in tongue shape and position resuting in simultaneous variation of vocal sound.

Therefore, this work offers an alternative pathway to the conventional kinematic approach of controlling vocal tract movements like [1–3]. A qualitative pilot study on the proposed interface revealed that though the inexperienced users find it somewhat difficult to achieve target tongue movements quickly, they agree that this interface provides them with more variability of inputs and more intuitive understanding of the human voice synthesis. Hence, it can be concluded that the proposed force-activated vocal sound controller is indeed a step towards natural articulatory speech production.

Acknowledgments

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References

[1] Neil Thapen. Pink Trombone. https://dood.al/pinktrombone/, 2017. version 1.1.

[2] Mark Huckvale. VT Demo. https://www.phon.ucl.ac.uk/resource/vtdemo/, 2010.

[3] Pramit Saha, Venkata Praneeth Srungarapu, and Debasish R. Mohapatra. Sound stream: Towards vocal sound synthesis via dual-handed simultaneous control of articulatory parameters. 2018.

[4] Ian Stavness, John E Lloyd, Yohan Payan, and Sidney Fels. Coupled hard–soft tissue simulation with contact and constraints applied to jaw–tongue–hyoid dynamics. *International Journal for Numerical Methods in Biomedical Engineering*, 27(3):367–390, 2011.

[5] Kees van den Doel and Dinesh K Pai. Jass: a java audio synthesis system for programmers. 2001.

[6] Yizhong Johnty Wang. *Investigation of gesture control for articulatory speech synthesis with a bio-mechanical mapping layer*. PhD thesis, University of British Columbia, 2012.

LIMITATIONS OF SOURCE-FILTER COUPLING IN PHONATION

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1 Introduction

As per the traditional source-filter theory, every acoustic speech synthesizer requires a voice source model to produce acoustic energy and a filter which could modulate that energy to produce speech like sound. These models could be categorized into three sections: parametric glottal flow models, kinematic vocal fold models and self-oscillating biomechanical vocal fold models. The parametric glottal flow model assumes that the voice source and vocal tract *filter* are linearly separable. But the current research in speech science precisely illustrates the impact of acoustic loading on the dynamic behaviour of the vocal fold vibration as well as the variation in the glottal flow pulses' shape. Both the kinematic and self-oscillating vocal fold models consider the source-filter interaction.

This study outlines the source-filter theory; elucidates various low-dimensional lumped-mass models of the acoustic source and computational models of the vocal tract as articulation. To understand the limitations of source-filter interactions which are associated with each of these models, we considered their mechanical design, acoustic and physiological properties and aerodynamic simulation.

2 Nonlinear Source-Filter Interaction

The acoustic interaction between the vocal cord and vocal tract is a growing interest in the study of articulatory speech production. The source-filter interaction refers to the properties of the vocal tract model which affect the self-oscillating characteristics of the acoustic source. These properties play a significant role in the designing of an articulatory speech synthesizer. In literature the source filter interaction has been demonstrated by considering the following effects: skewness in glottal flow wave, truncation, dispersion and superposition.

In retrospect, the classic linear source-filter theory [1] assumes human speech generation as a two-stage independent process. First, the glottal source produces air pulses of multiple fundamental frequencies F_0 which traverses through the vocal tract *(filter)*. The vocal tract acts like an acoustic modulator and it resonates only at formant frequencies F_1 to produce a time-varying glottal flow as output. This process has been demonstrated in Fig. 1. The linearly separable source-filter models could be represented mathematically as the convolution of the source and filter function in time domain or multiplication in frequency domain.

Though the linearity assumption for source-filter coupling is useful to build an over-simplified model, physiological systems are generally non-linear. And the linear coupling is only suitable where the fundamental frequencies of the source do not cross over the formant frequencies like in male speech voice. But for female or child speech voice and even while singing, it has been observed that the fundamental frequencies are in the proximity of the formant frequencies. And during that case, there is a high degree of variation in the vocal tract impedance which may cause intense interaction between the source and filter models. That could possibly lead to bifurcations in the dynamics of vocal fold vibration, sudden F_0 jumps and variation in the source energy [2]. Hence, to produce the actual speech like sound we should consider the nonlinear and time varying characteristics of source-filter coupling.

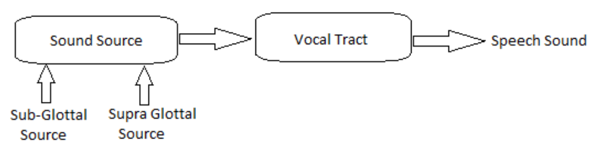

Figure 1: Flow diagram showing the Source-Filter process

3 Speech Synthesizer Models

There is a multitude of source-filter models in the literature which are successfully implemented. Most of these self-oscillating source models could be organized in two categories: lumped-element and continuum mass models. Though continuum models provide a better representation of the vocal fold, they are complex and computationally expensive. So for simplification, we analyzed only the lumped-element models of the vocal fold. Despite their simplicity, these models were shown to be able to generate many characteristics of an actual vocal fold oscillation. They represent the vocal fold as point masses which are connected to a rigid wall through springs [3]. Fig. 2 demonstrates the lumped-element models. To analyze the effect of acoustic loading, various computational models of the vocal tract are coupled with the acoustic source models.

3.1 Source Models

The one-mass model of the vocal fold was designed with a single mass-spring oscillator, driven by airflow from lungs. The point mass is assigned with a fixed weight which could emulate the vocal fold. And the spring system helps the point mass to oscillate to create air pulses with a particular glottal frequency [4]. Although the model can simulate acceptable voiced sound for an inductive acoustic load, it fails to sustain the self-oscillatory behaviour of the source for a capacitive load of the vocal tract, i.e. when the fundamental frequencies are just above the formants [3]. Because the one-mass model has only one degree of freedom, it could not produce

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the phase difference between the upper and lower vocal cord edges during oscillation.

Unlike the one-mass model, the two mass model of vocal fold [5] has successfully demonstrated the self-oscillating characteristics of the vocal fold. And the oscillation sustains for both the inductive and capacitive load of the vocal tract. Two mass model uses two mass elements per vocal cord and provides the necessary degree-of-freedom to introduce the vertical phase difference in vocal fold edges during oscillation. However, the main disadvantage of both of these models is that their tissue discretization in a coronal plane does not capture the layered structure of the vocal folds. And there is no immediate correlation between the spring stiffness and the effects of muscle contractions. From speech synthesis point of view, the most significant factor in the two-mass model is the characterization of its performance when its coupled with a transmission line model of the vocal tract.To investigate the performance of a two-mass model, Ishizaka et al. measured the onset frequency of the jumps for a large acoustic load on the model and compared the result with the same acoustic load in human voicing. For the two-mass model, the jump in the fundamental frequency happens at the first resonant frequency of the tube. Whereas in human voicing onset frequency of the jumps is higher than the first formant frequency [5].

The limitation of layered structured representation in two-mass type models motivated to design the body-cover structure of vocal folds. Mostly its a three-mass model that adds a “body” mass lateral to the two cover masses. Though the structural representation of the body-cover model is different, this model still preserves the self-oscillatory principle of the two-mass model. By controlling the body stiffness constant, the body-cover model of vocal fold could be reduced to a two-mass model.

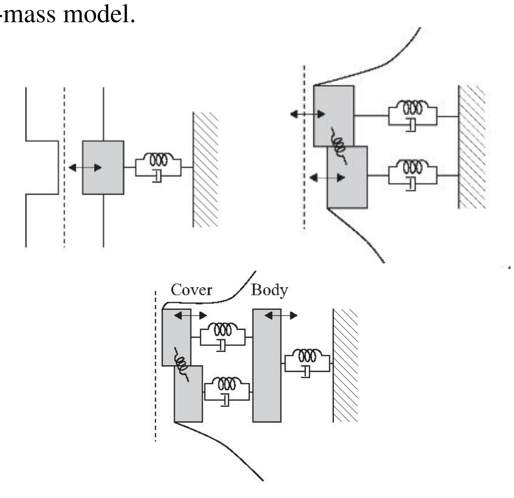

Figure 2: Lumpled-Element models of vocal fold. Image by Peter Birkholz [3]

3.2 Filter Models

The vocal tract acoustic load has both positive and negative types of damping terms. The negative damping which helps in vocal fold oscillation, is provided by the vocal tract inertance. There are numerous articulatory models exist in the literature which could produce this favourable condition. The Kelly-Lochbaum model of the vocal tract is traditionally constructed by approximating the cross-sectional area of the vocal tract by cascading multiple cylindrical tube sections [6]. The resulting tube system then could be interpreted as a digital waveguide or digital wave model of the vocal tract. But the severe pitfalls in this model are: 1) length of each of the cylindrical tube section has to be equal. 2) the junction of two tube section is not smooth. These limitations affect the formant frequencies of the articulatory model which in turn prevent to achieve the exact matching of a given speech spectrum.

4 Conclusions

The limitation in source-filter interaction for various models has been discussed. One of the significant challenges in designing a speech synthesizer model is to address the degree of interaction between the vocal fold and vocal tract which varies based on the types of articulatory gestures like singing; breathy voice; male or female voice; high and low pitch voice. So it is much needed to do an accurate measurement of the shape changes in vocal tract during articulation and the precise simulation of vocal fold and vocal tract interaction using a feedback channel. Hence, for a specific change in the vocal tract shape, there could be a notable impact on the vocal fold oscillation and glottal flow which is an input to the resonator. A fruitful direction could be the use of 2D Finite-Difference Time-Domain wave solver and the excitation mechanism while maintaining the stability of the solver when the domain boundaries (i.e., the vocal tract walls) are dynamically modified, as in the case of articulation.

5 Acknowledgement

This work was funded by the Natural Sciences and Engineering Research Council (NSERC) of Canada and Canadian Institutes for Health Research (CIHR).

References

[1] Fant Gunnar. The acoustic theory of speech production. *S'Gravenhage, Mouton*, 1960.

[2] Ingo R Titze. Nonlinear source–filter coupling in phonation: Theory. *The Journal of the Acoustical Society of America*, 123(4):1902–1915, 2008.

[3] Peter Birkholz, BJ Kröger, and P Birkholz. A survey of self-oscillating lumped-element models of the vocal folds. *Studientexte zur Sprachkommunikation: Elektronische Sprachsignalverarbeitung*, pages 47–58, 2011.

[4] J Flanagan and Lois Landgraf. Self-oscillating source for vocal-tract synthesizers. *IEEE Transactions on Audio and Electroacoustics*, 16(1):57–64, 1968.

[5] Kenzo Ishizaka and James L Flanagan. Synthesis of voiced sounds from a two-mass model of the vocal cords. *Bell system technical journal*, 51(6):1233–1268, 1972.

[6] Vesa Välimäki and Matti Karjalainen. Improving the kelly-lochbaum vocal tract model using conical tube sections and fractional delay filtering techniques. In *Third International Conference on Spoken Language Processing*, 1994.

SPEECH-LIKE MOVEMENTS EMERGE FROM SIMULATED PERIORAL MUSCLE ACTIVATION SPACE WITHOUT NEURAL CONTROL

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1 Introduction

Models of speech production to date have lacked realistic and comprehensive properties of physical bodies (see [1]), leaving open the possibility that some mechanisms hitherto ascribed neural control may be reinterpreted as being due to the properties of the biomechanics of the human vocal tract [2, 3]. For example, while neuromuscular modules (muscle synergies) [4] have been proposed as a solution to the degrees of freedom problem in speech biomechanics [5], experimental approaches involving the extraction of muscle synergies are theoretically unable to determine whether such synergies are of neural origin or simply reflect the lower dimensionality of an under-sampled biomechanical/neural task space [6].

As a proof of concept to test the extent to which vocal tract biomechanics may determine speech and expressive facial movements, we created a simplified version of the perioral region using FEM modeling in a physics-based simulator [7]. Systematic simulations using this model enable us to sample the full kinematic/biomechanical space [8, 9] in the absence of central neural control. We aim to use this model to test whether emotive and speech-like movements emerge as self-organizing structures (muscle synergies) in the absence of a direct neural controller.

2 Method

2.1 Model design

We developed a Perioral Simplified Model (POSM) using ArtiSynth (artisynth.org) with significantly reduced degrees of freedom compared to the full face models in Artisynth (see, e.g., [10]). Simplifying the model increased model robustness and stability, reduced computation time, increased model clarity, and allowed analysis techniques to be developed for future use in more complex models.

A finite elemental model (FEM) torus was fitted to the BadinFemMuscleFaceDemo in ArtiSynth to create a simplified biomechanical model of the perioral region (Figure 1). This allows a volumetric, rather than "deformed skin", simulation to be used, which deforms according to material properties of human muscle, skin, and fascia. Five muscle groups were modeled: Marginal and peripheral orbicularis oris (*OOM* and *OOP*, respectively) models use transversely-isotropic FEM-model muscle material and contract in a sphincter-like manner; the *OOP* incorporates separate models for medial and distal concentricities (*OOPm* and *OOPd*) to balance model simplicity with anatomical observation [11]. In addition, two series of point-to-point muscles represent left and right zygomaticus complexes (*ZYGM-l* and *ZYGM-r*, respectively). To capture the interdigitation of zygomaticus major/minor with the *OO* complex, we have modeled both *ZYGM* models with origins at the zygomatic bone and insertions at the mid-lateral FEM blocks containing the *OOP* muscle materials. The musculature for the POSM was selected to allow focus on the more reliably present and robust perioral muscles associated with speech and expression, based on the known wide range of perioral postures produced by the various layers and concentricities of *OO* [11] and the high variation and frequent absence of facial muscles such as risorius [12].

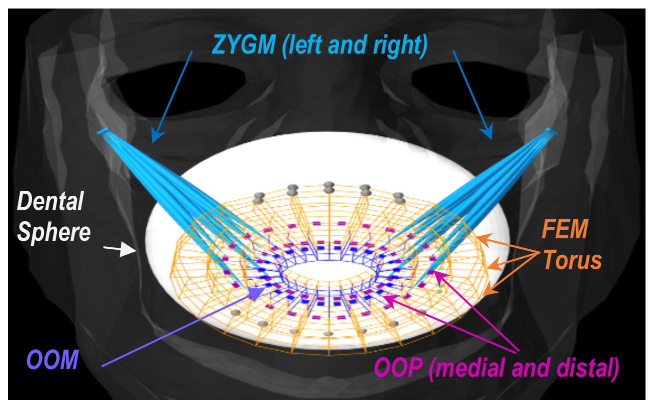

Figure 1: Detail of the perioral simplified model.

The skeletal structures for the POSM (mandible, maxilla, and dentition) are approximated using a smooth, rigid body ellipsoid, with four FEM block nodes fixed at the nasal bone. In addition to the skeletal surface yielding stable results during contact, this surface proved crucial as a backstop against which the model was able to deform, without which the speech and expressive postures were not possible.

2.2 Simulation methodology

All combinations of the five above muscles groups at four levels of activation (0, 0.1, 0.2, 0.3 of maximum excitation as values beyond these resulted in no posture change) were simulated sequentially using adapted Python scripts. Activation sequences were started at zero, held for 200 ms before activation, and achieved target activation after 1000 ms. Once model equilibrium was reached, the resulting posture for that simulation was saved using 3D coordinates for each FEM node as a flattened vector. Aggregation of these posture vectors resulted in a 15504 by 3456 matrix

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representing a discretized sampling of the biomechanical state space of our model.

2.3 Analysis methodology

Data were analyzed using t-distributed stochastic neighbourhood embedding (t-SNE) to show regions of the biomechanical space (see [13]) with post-hoc qualitative assessment of kinematic outputs (contact authors for t-SNE and ArtiSynth user-defined parameters). Analyses were repeated 20 times to minimize the objective function and construct a representative visualization of the data. Clusters of speech-like movements were visually obtained by comparing the activation of each muscle across individual simulations. Areas in the t-SNE visualization where one or two muscles show distributional constraint were corroborated in ArtiSynth to determine their qualitative similarity to speech-like or emotive expressions.

3 Results

Figure 2 plots the outputs of the simulations using t-SNE to cluster kinematically similar outputs. Qualitative evaluation revealed that the circled clusters in Figure 1 correspond roughly to lip spreading (top circled cluster), lip protrusion (middle circled cluster), and lip closure (bottom circled cluster).

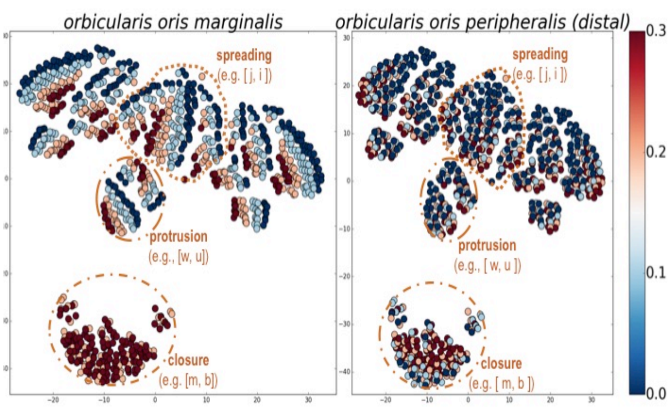

Figure 2 t-SNE (perplexity = 102) visualizations of the POSM state space (each data point corresponds to the output of a complete individual simulation). Left and right visualizations are coloured by muscle activation, here highlighting *OOM* and *OOPd*, respectively. All non-circled data points indicate simulations that display asymmetric postures due to increased force of one *ZYGM* exciter over another.

4 Discussion and conclusion

Systematic simulations enabled us to sample the full kinematic/biomechanical space. t-SNE visualizations of the resulting biomechanical state space show that clusters of similar movements emerge from this space without a direct neural controller, i.e., a uniform sampling of the activation space elicits non-uniform kinematic outputs. These clusters, moreover, fall into ecologically relevant qualitative categories (lip spreading, protrusion and closure), despite competing activation from surrounding muscles.

These results suggest that biomechanics may play a primary role in the near-universal emergence of specific movement categories in emotive and speech-related movements. Because we see similar postures appearing across human populations in speech and facial expression, our analysis suggests that the emergence of these postures may be due at least in part to robustness of these postures to activation noise from surrounding muscles.

The combination of numerical (ArtiSynth and t-SNE) and qualitative procedures used in this study allows us to determine whether similar postures that emerge from the kinematic and biomechanical state space in the absence of neural control resemble speech/emotive-like expressions, providing a proof-of-concept demonstration of this combination of methods as a way of capturing emergent output categories from biomechanical simulations.

Acknowledgments

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References

[1] Gick, B., Schellenberg, M., Stavness, I., & Taylor, R. (2018). Articulatory Phonetics. In W. F. Katz & P. Assmann (eds.). *The Routledge Handbook of Phonetics*. Ch 5. NY: Taylor & Francis.

[2] Kugler, P. N., & Turvey, M. T. (1987). *Information, natural law, and the self-assembly of rhythmic movement.* Hillsdale, N.J: L. Erlbaum Assoc.

[3] Stevens, K. (1989). On the quantal nature of speech. *J. Phon.*, 17(1-2): 3-45.

[4] Bizzi, E., & Cheung, V. (2013). The neural origin of muscle synergies. *Front. Compu. Neurosci.*, 7, 51.

[5] Gick, B., & Stavness, I. (2013). Modularizing speech. *Front. Psych.*, 4.

[6] Kutch, J., & Valero-Cuevas, F. (2012). Challenges and new approaches to proving the existence of muscle synergies of neural origin. *PLoS Compu. Biol.*, 8(5)

[7] Lloyd, J. E., Stavness, I., & Fels, S. (2012). ArtiSynth: A fast interactive biomechanical modeling toolkit combining multibody and finite element simulation. Berlin: Springer. P. 355-394.

[8] Kutch, J. J., & Valero-Cuevas, F. J. (2011). Muscle redundancy does not imply robustness to muscle dysfunction. *J.Biomech.*, 44(7), 1264-1270.

[9] Gick, B., Allen, B., Roewer-Despres, F. & Stavness, I. (2017). Speaking tongues are actively braced. *JSLHR* 60(3), 494-506.

[10] Gick, B., Stavness, I., Chiu, C. & Fels, S. S. (2011) Categorical variation in lip posture is determined by quantal biomechanical-articulatory relations. *Can. Acoust.* 39(3), 178-179.

[11] Stavness, I., Nazari, M.A., Perrier, P., Demolin, D. & Payan, Y. (2013). A biomechanical modeling study of the effects of the orbicularis oris muscle and jaw posture on lip shape. *JSLHR* 56(3): 878-90.

[12] Waller, B. M., Cray, J. J., Burrows, A. M. (2008). Selection for universal facial emotion. *Emotion* 8(3): 435–9.

[13] van der Maaten, L., & Hinton, G. (2008). Visualizing data using t-SNE. *J. Mach. Learn. Res.*, 9, 2579-2605.

TURNKEY SOLUTION PROVIDES NOISE REDUCTION IN MINE VENTILATION SYSTEM

Mehrzad Salkhordeh[*1]
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1 Introduction

A nickel and copper mine located in Ontario was in need of extensive upgrades and measures to bring operations into compliance with current environmental regulations. Upgrades to the mining ventilation system were the first on the list. In addition to a custom fan silencer system, the client needed a qualified source to provide engineering assistance and coordination throughout the multiple phases of the necessary upgrades.

Since mining operations run 24 hours day, seven days per week, the noise levels from the mine ventilation system were an on-going problem in the surrounding areas. Complicating the project was the condition of the existing ventilation enclosure, which was in need of extensive clean up, including the removal of hazardous material.

Figure 1: Before the ventilation system

2 Method

The db Noise Reduction® team worked with an acoustical consultant to develop a custom fan silencer solution for the 140,000 ACFM axial fans that were producing a noise level of 104 dBA combined, well above the regulated levels. An integral part of the project included disassembly of the existing steel structure to remove rust and corrugated asbestos. As a noise reduction specialist with an engineering focus, the db Noise Reduction® team was uniquely qualified to engineer and coordinate all phases of the project, providing a complete turnkey solution.

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3 Solution

The db Noise Reduction® team addressed all phases of the ventilation system upgrade through a series of operations that were completed within 9 months. For the first step, which was cleaning-up the structural steel, a CO2 blasting process was used. This avoided the need for environmentally harmful chemicals and eliminated the potential for dust and debris. This was essential in the process, since the fans needed to remain in operation during cleaning. A protective paint was applied to the steel structure.

Figure 2: After the ventilation system

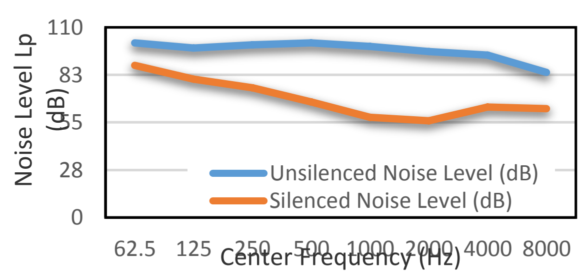

Figure 3: Measurements before and after silencing solution

The next step of the process included special precautions for the removal of the corrugated asbestos. This was the only part of the process during which the mine operation had to temporarily halt operation, due to potential asbestos exposure. The team coordinated the hazardous material removal with a certified removal team, who completed the job in less than a day. Following the excavation of the area, the newly cleaned and treated steel structural was then enhanced with the installation of four fan intake silencers, two acoustic walls, and an acoustic roof.

Yearly Reviewer List / Liste annuelle des évaluateurs

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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SUMMARY OF JOINT ASA/CAA CONFERENCE 2018

The joint 176th Meeting of the Acoustical Society of America and the Canadian Acoustical Association's Acoustics Week in Canada 2018 was held Nov. 5-9, 2018, in beautiful Victoria, B.C. The conference covered all areas of acoustics, organized according to the ASA's 13 Technical Committees, with a special focus on marine acoustics and bioacoustics, in keeping with the natural coastal setting of Victoria. Over 1300 registrants attended and a similar number of technical papers were presented, making this one of the largest ASA meetings in recent years. As the CAA did not hold a meeting of their own in 2018, formal CAA activities such as the Board of Directors' Meeting, Standards Meeting, Annual General Meeting, and Awards Ceremony were all included as part of the joint event. The conference did not include an Exhibition of acoustics equipment and services, a common feature of regular CAA annual meetings.

The conference was held in the adjoining facilities of the Victoria Conference Centre and the Fairmont Empress Hotel, situated in Victoria's most prestigious location fronting directly on the Inner Harbour Walkway and just steps from the grand B.C. Legislative Building, Royal B.C. Museum, and Government Street pedestrian mall. Most of the technical sessions were held in the Conference Centre, which features an open west-coast, First-Nations décor. The Empress Hotel, a National Historic Site of Canada, provided elegant and unique committee and reception rooms. A buffet social event was held on the Tuesday night of the conference at the Royal B.C. Museum (regularly rated the best museum in Canada), with catering and drinks stations distributed throughout immersive exhibits of the natural and human history of British Columbia, with particularly impressive First Peoples Gallery and Totem Hall. A second buffet social was held on the Thursday night in the Crystal Ballroom at the Empress Hotel, featuring fare inspired by Victoria's traditions and ethnic heritage including fish-and-chips and dim sum.

Planning for the joint conference began 4 years earlier when the ASA sought a local organizer to take on a conference in either Victoria or Vancouver for the fall of 2018. Stan Dosso agreed to take the role of Conference Chair for a Victoria meeting and immediately engaged Roberto Racca as Technical Chair, reuniting a pairing who had worked together in these roles to run CAA meetings in Victoria in 2010 and in Banff in 2012. Stan and Roberto assembled a Local Organizing Committee, largely composed of CAA members, including Xavier Mouy and Sonya Bird (social programs); Graham Warner, Jorge Quijano and Amalis Riera (A/V and Room Monitoring); Tom Dakin, Svein Vagle and Kristen Kanes (Signage); and Shelley Dosso (Accompanying Persons' Program).

The organizers found it a pleasure to work with both the ASA and CAA in convening this joint meeting and bringing to Canada such a large number of acousticians from the United States and the world.

Stan Dosso & Roberto Racca

Photo Gallery

Fairmont Empress Hotel on Victoria's Inner Harbour.


Victoria Conference Centre (front) and Empress


British Columbia Legislative Buildings lit at night.


Victoria Conference Centre Entrance Hall.

Empress Hotel Palm Court.

Royal B.C. Museum Totem Hall (Tuesday Buffet Reception)

Canadian Acoustical Association
Association canadienne d'acoustique

2018 PRIZE WINNERS / RÉCIPIENDAIRES DES PRIX 2018

EDGAR AND MILLICENT SHAW POSTDOCTORAL PRIZE IN ACOUSTICS /
PRIX POST-DOCTORAL EDGAR ET MILLICENT SHAW EN ACOUSTIQUE

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PRIX ETUDIANT BELL EN COMMUNICATION VERBALE ET AUDITION

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

Josse Belcourt (University of Victoria)

ECKEL GRADUATE STUDENT PRIZE IN NOISE CONTROL /
PRIX ETUDIANT ECKEL EN CONTROLE DU BRUIT

Vincent Nadon (École de technologie supérieure)

ALBERT S. BREGMAN GRADUATE STUDENT PRIZE IN PSYCHOLOGICAL ACOUSTICS /
PRIX ETUDIANT ALBERT S. BREGMAN EN PSYCHOACOUSTIQUE

Sean Gilmore (Ryerson University)

THOMAS D. NORTHWOOD STUDENT PRIZE IN ARCHITECTURAL AND ROOM ACOUSTICS /
PRIX ETUDIANT THOMAS D. NORTHWOOD EN ACOUSTIC ARCHITECTURALE ET DES SALLES

Magdalenn Bahour (Ryerson University)

Award winners **Megan Keough** (top Left), **Josse Belcourt** (top right), **Vincent Nadon** (bottom left), and **Sean Gilmore** (bottom right), with Awards Coordinator Prof. Joana Rocha and President Prof. Jeremie Voix, at the Awards Ceremony during the Acoustics Week in Canada 2018 in Victoria

Récipiendaires des prix de l'association, **Megan Keough** (en haut à gauche), **Josse Belcourt** (en haut à droite), **Vincent Nadon** (en haut à gauche), and **Sean Gilmore** (en haut à droite), avec le coordinateur des prix Prof. Joana Rocha et présidente Prof. Jeremie Voix, à la cérémonie de remise des prix lors de la Semaine Canadienne d'Acoustique 2018 à Victoria

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 Hetu 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 etudiant Alexander G. Bell en Communication orale et audition (2^{e} ou 3^{e} cycle)
Prix etudiant Eckel en Controle du bruit (2^{e} ou 3^{e} cycle)
Prix etudiant Fessenden en Acoustique sous-marine (2^{e} ou 3^{e} cycle)
Prix etudiant Raymond Hetu en Acoustique (1er cycle)
Prix etudiant Thomas D. Northwood en Acoustique Architecturale et Acoustique des Salles (2^{e} ou 3^{e} cycle)
Prix etudiant Albert S. Bregman en Psychoacoustique (2^{e} ou 3^{e} cycle)

Deadline for Applications:
April 30^{th} 2019

Date limite de soumission des demandes:
30 Avril 2019

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

CANADIAN ACOUSTICAL ASSOCIATION
ASSOCIATION CANADIENNE D'ACOUSTIQUE

ACOUSTICS WEEK IN CANADA 2019 – Edmonton AB

October 9-11, 2019
Sutton Place Hotel Edmonton

Welcome to Edmonton!

Edmonton looks forward to welcoming delegates to the 2019 Acoustics Week in Canada. Acoustics researchers, professionals, educators, and students from across the country are welcomed to Alberta's Capital for 3 days of plenary lectures and technical sessions. The Canadian Acoustical Association Annual General Meeting will be held in conjunction with the conference, along with the Acoustical Standards Committee Meeting, the conference banquet, and an exhibition of acoustical equipment and services.

Plenary Lectures/Technical Sessions

Acoustics Week in Canada 2019 will feature three plenary lectures covering current acoustical topics, and highlighting regional expertise and situations. Technical sessions will cover all major areas of acoustic interest, including Hearing Loss Prevention, Acoustical Standards, Architectural Acoustics, Noise Control, Shock and Vibration, Hearing and Speech Sciences, Musical Acoustics, Underwater Acoustics, Bioacoustics, and other topics.

Exhibition & Sponsorship

There will be an exhibition area for acoustical equipment, products, and services on Thursday October 10. If you or your company is interested in exhibiting, or if you would be interested in sponsoring a conference social event, technical session, coffee breaks, or student prizes, please contact the **Exhibition Coordinators.** The conference offers an excellent opportunity to showcase your company and products or services.

CANADIAN ACOUSTICAL ASSOCIATION
ASSOCIATION CANADIENNE D'ACOUSTIQUE

ACOUSTICS WEEK IN CANADA 2019 – Edmonton AB

Student Participation

Students (graduate and undergraduate) are enthusiastically encouraged to attend the conference. Travel subsidies and reduced registration fees will be available. Student presenters are also eligible to win prizes for best presentations.

Paper Submissions

The abstract deadline is June 14, 2019. Two-page summaries for publication in the proceedings of Canadian Acoustics are due by July 15, 2019. Please see further details on the conference website: http://awc.caa-aca.ca/

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CANADIAN ACOUSTICAL ASSOCIATION
ASSOCIATION CANADIENNE D'ACOUSTIQUE

ACOUSTICS WEEK IN CANADA 2019 – Edmonton AB

Du 9 au 11 octobre 2019

Sutton Place Hotel Edmonton

Bienvenue à Edmonton !

Edmonton se réjouit d'accueillir les délégués de la Semaine canadienne d'acoustique 2019. Des chercheurs en acoustique, des professionnels, des éducateurs et des étudiants de partout au pays sont invités à la capitale de l'Alberta pour trois jours de séances plénières et de sessions scientifiques. L'assemblée générale annuelle de l'Association canadienne d'acoustique aura lieu en conjonction avec le congrès, ainsi que la rencontre du comité de normalisation en acoustique, le banquet du congrès, et une exposition d'équipements et de services acoustique. Le congrès se tiendra à l'hôtel Sutton Place Hotel Edmonton.

Séances plénières et sessions scientifiques

La Semaine canadienne d'acoustique 2019 mettra en vedette trois présentations plénières dans des domaines actuels d'intérêt en acoustique et mettant en évidence l'expertise et le cadre régional. Des sessions scientifiques porteront sur tous les domaines principaux d'intérêt en acoustique, y compris la prévention des pertes auditives, la normalisation, l'acoustique architecturale, le contrôle du bruit, les chocs et les vibrations, l'audition et les sciences de la parole, l'acoustique musicale, l'acoustique sous-marine, la bioacoustique marine, et d'autres sujets.

Expositions et commandites

Il y aura un espace d'exposition pour l'équipement en acoustique, les produits et les services le jeudi 10 octobre. Si vous ou votre entreprise êtes intéressé à exposer, ou si vous êtes intéressé à commanditer un événement social du congrès, une session scientifique, des café pauses, ou des prix d'étudiants, veuillez contacter **le coordonnateur de l'exposition.** Le congrès offre une excellente occasion de présenter votre entreprise et vos produits ou services.

CANADIAN ACOUSTICAL ASSOCIATION
ASSOCIATION CANADIENNE D'ACOUSTIQUE

ACOUSTICS WEEK IN CANADA 2019 – Edmonton AB

Participation des étudiants

Les étudiants de premier cycle et des cycles supérieurs sont chaleureusement encouragés à participer au congrès. Des subventions de voyage et les frais d'inscription réduits seront disponibles. Les présentateurs étudiants sont également admissibles à gagner des prix pour les meilleures présentations.

Soumissions

La date limite pour les résumés est le 14 juin, 2019. Des articles de deux pages pour publication dans les actes de congrès sont dues le 15 juillet, 2019. Veuillez voir plus de détails sur le site de la conférence:
http://awc.caa-aca.ca/

Contacts / Comité d'organisation

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SITE WEB DU CONGRÈS
https://awc.caa-aca.ca/

CAA-ACA BOARD OF DIRECTORS MEETING

November 4th, 2018

Meeting called to order at 15:05.

Present in room: Frank, Umberto, Andy, Mehrzad, Jeremie, Dalila, Roberto, Bryan, Michael.

Remote: Hugues, Bill.

Missing: Alberto and Joanna.

1. Motion to adopt agenda

Made by Jeremie, seconded by Umberto.

2. President's Report (Jeremie)

Some board members are due for renewal. Roberto and Mehrzad expressed their willing to remain. Moreover, all others also expressed their agreement to stay on.

The award committeeis not anymore chaired by Hugues, but has passed to Joanna.

The president adjourned about some updates in the website. The photos and info clips of Board members were added online at CAA-ACA web site. Moreover, logos and contact info of sustaining subscribers are now automatically linked to web page.Past conferences web information is now properly archived and accessible from web site, and all broken links in the web site were removed. Finally, the web site now renders properly on all device sizes thanks to the effort of the website work done by Philip Tsui.

Regarding the ASA Fall 2018 meeting, the main discussion regarded: No presentation awards this year, but major prizes were awarded; Proceedings will include 2-page papers from CAA authors (voluntary) in December 2018, while authors can also submit to POMA.

Regarding the opportunities from joint CAA-ICSV conference in Montreal in July 2019:

- CAA booth was discussed; can be very beneficial for membership and we can display copies of the journal and give away samples.
- In past events visitors, could get signed up for free electronic copy only membership, which led to some full renewals at the end of the first year. Agreed to look at creating a special category of complimentary membership that will be tracked separately.
- Not enough Board members committed to attend ICSV event to make it worthwhile to hold BoD meeting there.
- Special ICSV26 journal proceedings in summer 2019; invitation will be sent out by Editor in Chief.

Requests for Special Membership.

- Request for local chapter membership came from John Swallow of Toronto chapter in August 2018. Discussion found no good reason for doing that but will take into consideration for review after John's guest presentation.
    - John joined meeting at 15:30 (left at 15:50) to give a brief presentation on the Toronto chapter.
    - General knowledge, local facilities, history and background, not competing with CAA annual meeting but more like mini plenary seminars.

- Three chapter meetings in 2017-18 year with presentations on room acoustics, hearing loss in musicians, building code, and more.
- Attendance ~45, exclusive of organizers.
- Held at Ryerson courtesy of Umberto.
- Three-Four Chapter Meetings for 2018-2019; potential events could include tour of McMaster LiveLab, and a joint meeting with Montreal.
- Requesting of CAA Board:Continued support and encouragement; Budget of around $1000 a year against documented expenses; Consider a "Limited CAA membership" designation providing only Chapter attendance privileges.
- Some discussion of merits of CAA support vs potential for leading to local groups starting willy-nilly with little substance; as for local chapter membership, it could erode from the value of actual CAA membership.

- Request from John Peppin for multi-year memberships as well as lifetime or emeritus membership. Currently a single lifetime membership.

Jeremie closed by thanking Board for expressing support for his application for the ICA early career award, and especially Christian Gigure for writing a letter of support.

3. Social media outreach (Frank)

Frank wishes to step out of the role, but no apparent successor can be identified. Frank has benefited by news stories being fed to him by a couple of students; he could stay on if he had additional support from a broader basis of students; suggestion to put out a call at the AGM.

4. Awards report (Joana)

No formal report was received, but Joana submitted a full list. Winners to be recognized during the ASA/CAA conference plenary session on Wednesday afternoon. Joana should be preparing the certificates. Dalila will prepare all associated cheques.

Awards now have greater exposure on the CAA-ACA web site including list of past winners.

5. Past and upcoming meetings

AWC 2017 – Peter VanDelden submitted a report that contains a substantial amount of detail.

ASA/CAA 2018 – Roberto reported some 1000 papers and around 1200 attendees expected. No benefit or liability to the CAA from the event. Difficult to track CAA registrants, and there was some dissatisfaction voiced in e-mails with lack of an exhibition or opportunity to sponsor.

2019 ICSV26 – The CAA is co-organizing and is 5% participating in gains or losses. Jeremie gave a brief overview of keynote speakers and other details; very high-profile event with very international attendance (expected between 800 and 1000). Does feature an exhibition (32 booths) and has a sponsorship program. Business meeting events organized by NATO and by Québec MSSS-MDDELCC Ministry.

AWC 2019 – Conference President designate Benjamin Tucker was in attendance throughout the BoD meeting and gave an overview of the initial organizing. AWC 2019 will be held in Edmonton at the Sutton Place, on October 9-11.Good involvement of academia and industry in the organizing committee. Benjamin will work with Dalila to organize the seed funding and look at strategies for student travel support. Benjamin's intent is to keep registration fees as low as possible, especially for students, but Board noted that some consistency between AWC editions should be maintained.

AWC 2020 – Jeremie mentioned that conference should be moving east again after 2019 and that St John's (NF) was a possibility, but there is a more concrete though tentative interest from Sherbrooke (QC). Frank proposed to contact Ben Zendel and Yvan Rose at Memorial to see whether St John's option is viable.

Frank gave a quick update on the Conference manual; a draft has been prepared but needs expansion of various points. Frank will send out another call to the task committee in January.

6. Treasurer's Report (Dalila)

Looking at reinvestment of high-yield funds now coming to maturity. Interest not as attractive as in the past.Budget to be adjusted with awards amounts paid out ($9,500).

Taxes filed; received a large GST refund.

$47,000 raised by Guelph conference. But, very low collection rate for journal advertising fees.Journal costs this year were down because a proceedings edition was not produced. Next year will be back to normal, so full amount has to be budgeted for next year.

Dalila noted that last increase in rates was in 2014 and we should be looking at an adjustment. There was some discussion of ways to put the budget on a surer footing, including ways to recover unpaid amounts from delinquent advertisers. Mehrzad pointed to increasing disconnect between the content of the Journal and the audience that the industrial / manufacturing advertisers are seeking to reach, which leads to low interest in advertising.

Dalila put forward the idea to increase rates; after discussion,the sense was that the rates should be kept low for students, but the regular rates could be increased by $10. Moved by Dalila; seconded by Frank; carried unanimously.

Moved by Dalila, seconded by Mehrzad to accept Treasurer report; carried unanimously.

7. Secretary's Report (Roberto)

Agreed to have a more streamlined interaction with Umberto and the Journal team to deal with matters of circulation such as non-received issues and other points raised especially by subscription agencies.

8. Editor's Report (Umberto)

Unusual year for the Journal because the September (conference) issue was a regular issue instead; intent was to have the December issue fill that role but few 2-page papers have been received. The Vancouver / BC issue in June 2018 also turned out more of a hybrid than a dedicated special issue.

The March 2019 issue will be a Special Issue about Audiology, guest edited by Olivier Valentin. Journal is discussing with ICSV the opportunity of a "special issue" in conjunction with the Montreal ICSV26 conference (June 2019); the September 2019 issue will be the conference issue for the Edmonton AWC.

Umberto is still working at achieving an optimal composition of the Journal, to have a good balance of full peer-reviewed technical articles (strong interaction with authors, aiming to no rejection but rather adaptation of articles until suitable), special-topic short articles, and focus interest features like the Practitioner's Corner. Discussion took place on how to improve communications during the submission and review process, looking at various case examples to pinpoint areas of improvement.

Deputy editor has proposed to start curating a CAA Archives and History project. Stories could be contributed by the CAA membership based on personal memories, historical facts and anecdotes. Histories of distinguished acousticians would be another component.

9. Other Matters

Dalila asked about charges assessed by the ASA for CAA-ACA activities at the 2018 conference, such as the Standards meeting; Jeremie confirmed that we would be responsible for such charges, as we were in the past through regular AWC events.

Next Board of Directors meeting: Spring 2019 by online portal.

10. Adjournment

Motion to adjourn made at 18:10 by Dalila; seconded by Jeremie.

CANADIAN ACOUSTICAL ASSOCIATION

Annual General Meeting

November 7th, 2018

1. Call to order

- Meeting called to order at 4:30 PM by Jeremie Voix (President).
- Approximately 40 people in attendance.

2. President's report (Jeremie Voix)

- Online system has been further updated.
- Recognition of sustaining member.
- Web site is now compliant with smart phones.
- ICSV26 to be hosted in Montreal with CAA as a supporting organization.
    - We stand to gain if the meeting is cash positive but no risk for losses.
- We plan to have a CAA booth.
    - Volunteers are welcome to support the booth which is intended to drive up membership.
- Presentation of Jeremie Voix for the ICA award.
- All of the members on the board who have elected to stay on. Thank you to those members for staying on.
- Greatly appreciate Roberto Racca for staying on for another 4 years.

3. Treasurer's report (Jeremie Voix on behalf of Dalila)

- CAA is a non-profit organization.
- Item #2 in the treasurer's report is our list of investment accounts, which are all doing well.
- Very successful Guelph conference $47,000 in revenues.
- Treasurer has a $10K shortfall for the coming year. We did not spend a large amount on the journal as we did not execute a proceedings edition because of joint meeting with ASA.
- Proposed increase of $10 to full member annual membership
    - Jeremie Voix moves on behalf of Dalila Giusti to increase from $110 to 120; This raise has not happened in the last five years.
    - Ramani Ramakrishnan seconded the motion.
    - 22 hands raised (motion is passed); no objectors.

4. Secretary's report (Roberto Racca)

- We are proud to be companions in hosting the Victoria meeting.
- Membership numbers are modest but still on the rise.
- Guelph meeting helped to increase the membership.
- Reminder that we have decided to disassociate conference fees with automatic membership. Members continue to get a discounted rate, but there will be no automatic enrollment in membership.
- Student numbers are going up.
- We are tremendously grateful to our sustaining subscribers. They are the lifeblood of the society.
- We are trying to streamline the circulation of the journal. Working closely with Umberto (Berardi) to do this.

5. Editor-in-Chief's Report (Umberto Berardi)

- Invites membership to submit conference papers to appear in the December paper.
- Reminder about special issues coming in 2019.
  - Audiology and Neuroscience - March 2019.
  - ICSV – Murray special issue - June 2019.
  - Acoustics Week in Canada – September 2019.
- Friday there will be a special session regarding Murray Hodgson.
- Reminder that we are still taking papers for the practitioner's corner .
  - These undergo a light review, but we are working to balance issues between scientific papers while not losing traction with the practitioners.

6. Conference Update (Jeremie Voix and Benjamin Tucker)

- Upcoming meeting to take place in Edmonton.
- First meeting in Edmonton since 2003.
- Please consider coming to ICSV meeting in Montreal in 2019 (July). Focus on sound and vibration. First ICSV in Canada since 1994.
- Bids are still open for our 2020 meeting. We are currently working on two proposals, but we welcome other bids.
- Thank you to Andy Metalka for taking photos, some of which will appear in the journal.

7. Questions

A concern was expressed from a member on the floor regarding the lack of action on impact noise. There was some discussion in Guelph about a working group to study the matter but no action has been taken. President Voix encouraged the member to push the agenda forward at the upcoming ICSV in Montreal.

8. Call for Adjournment

Ben Tucker moves to adjourn the meeting; seconded by Andy Metalka.

CAA Standards Meeting Minutes

November 4, 2018

Victoria BC

Present:

Tim Kelsall – Chair

Jean-Philippe Migneron

Andy Metelka

John Swallow

Bill Gastmeier – Phone

Stephen Keith - Phone

1. Welcome – Explanation that the ASA Board had invited the CAA Board for dinner at the same time as this meeting and thus many members had to be absent.

2. Appointment of Minutes Taker – Tim Kelsall

3. Approval of agenda - Approved

4. Approval of Minutes

5. Update since last meeting

6. CAA 101

   French Translation drafted by Pier-Gui Lalonde, P.Eng., ing., Integral DX Engineering Ltd. French speaking committee members are requested to review before next meeting.

7. Items from CAA board (not available as board members could not attend)

8. Update From Subcommittees

    a. Environmental Noise (Bill Gastmeier) see attached
       Impulse noise in NPC 300 not yet updated but ISO 1996-3 considered a possibility
    b. Wind turbines – Brian Howe – no report
    c. CAC TC43 SC1, - Stephen Keith – see attached
       Stephen has nearly completed the term he is allowed. To help spread the load several Vice-Chairs (listed) have been appointed responsible for particular types of standard within their specialties
    d. IEC, Instrumentation – Lixue Wu – no report
    e. Z107.10 / Editorial (Dave Quirt) – no report
    f. Building Acoustics ISO/TC43/SC2 and ASTM E33 – David Quirt – no report
    g. Human Vibration ISO TC 108/SC4 (Tony Brammer) – see attached
    h. Loudness Evaluation – Colin Novak

9. New Business

   J.P. Migneron mentioned that the Province of Quebec Ministries of Environment and Transportation have commissioned 3 Universities to study improvements in assessing human reaction to noise along the lines of the WHO report concerning the effects of noise on residential communities.

   The occupational noise regulation is no longer a priority for updating but the Ministry of Health has recommended an 85/3 criterion.

10. Next Meeting Spring – by phone

Subcommittee Reports:

Building Acoustics – David Quirt

- From my perspective there are no major changes from my last report.
- The ISO standards that provide part of the foundation for building code requirements were approved last year, and will probably not have further major revisions for several years. In due course I expect the Code will switch to the new version, now denoted as ISO 12354.
- Attempts to add structure-borne flanking to the ASTM standards seems to be having little uptake – informed building science is not part of the Republican dream.

Like Stephen Keith I am in my last months as Chair of ISO/TC43/SC2 “Building Acoustics” but may continue in a reduced role.

2018 November Report on Standards Council of Canada Canadian Advisory Committee for ISO TC43 And TC43/SC1

New Standards Council of Canada term limits for ISO and IEC committee chairs

- A new chair must be found for this committee. According to SCC rules, a new chair must be nominated before December 31 2018. The chair is elected for a 3 year term, and can be reappointed for a maximum allowable time of 9 years.

Canadian Advisory Committee vice chairs

- The workload for this committee is high (see below). To reduce the effort required by the committee chair an unusually large number of vice chairs has been approved by the Standards Council of Canada.
- TC43 vice chairs
    - Helen U. - Loudness
    - Victoria M. - General audiology and hearing aid fitting
    - Christian G. - Hearing thresholds and close to the ear measurements

- TC43/SC1 vice chairs
    - Colin N. - vehicle noise, blocked forces, dynamic forces
    - Alberto B. - hearing protectors
    - Stephen K. - (alternate Tim K., Bill G.) machinery noise, IT equipment, orphaned standards
    - Bill G. - (alternate Tim K., Stephen K) environmental noise, sound propagation
    - Ann N. - shooting ranges
    - Catherine G. - soundscapes
    - Tim K. - air terminal devices, ducted silencers
- Orphaned standards – no vice chair
    - Airborne noise from vessels at sea
    - Annoyance
    - Office space sound quality
    - Noise prediction software
    - Pavement texture using surface profiles
    - Tire noise

International representation on ISO acoustics and noise committees

- 1 project leader, 1 international secretary, 1 member TC43 advisory panel, 20 subject matter experts

Workload, in past year

ISO/TC43 –Reviewed 3 new drafts and reaffirmed 4 published standards. Approved the following final draft for publication

ISO 389-1 (Ed 2) - Acoustics -- Reference zero for the calibration of audiometric equipment -- Part 1: Reference equivalent threshold sound pressure levels for pure tones and supra-aural earphones

ISO/TC43/SC1 – Reviewed 7 new draft and reaffirmed 20 published standards. Abstained on drafts related to ships and SC2 (on office space quality).

Approved the following 6 final drafts for publication

ISO 7779 (Ed 4) - Acoustics -- Measurement of airborne noise emitted by information technology and telecommunications equipment

ISO 11200 Amd 1 - Acoustics -- Noise emitted by machinery and equipment -- Guidelines for the use of basic standards for the determination of emission sound pressure levels at a work station and at other specified positions -- Amendment 1

ISO 17201-1 (Ed 2) - Acoustics -- Noise from shooting ranges -- Part 1: Determination of muzzle blast by measurement

ISO 4869-1 (Ed 2) - Acoustics -- Hearing protectors -- Part 1: Subjective method for the measurement of sound attenuation

ISO 4869-2 (Ed 2) - Acoustics -- Hearing protectors -- Part 2: Estimation of effective A-weighted sound pressure levels when hearing protectors are worn

ISO 3743-2 (Ed 2) - Acoustics -- Determination of sound power levels of noise sources using sound pressure -- Engineering methods for small, movable sources in reverberant fields -- Part 2: Methods for special reverberation test rooms

Voted disapproval of the following final 2 drafts for publication

ISO 17201-3 - Approval for layout for ISO/FDIS 17201-3

ISO 12913-2 - ISO/DTS 12913-2 "Acoustics - Soundscape - Part 2: Data collection and reporting requirements".

General ISO/TC43 and ISO/TC43/SC1 are responsible for 153 standards which are frequently revised, and are systematically reviewed every 5 years.

Upcoming ISO Meetings

- Matsue, Japan November 2018. International delegates Stephen K., with others by teleconference.
- Standards Council of Canada has allocated enough money to allow full compensation for travel, but no other delegates will be travelling to meetings this year.

Active members are needed on this committee; those interested in participating should contact Stephen Keith, skeith@hc-sc.gc.ca

Stephen Keith

Report of Subcommittee on Human Vibration
to
CAA Standards Committee
November 03, 2018

The subcommittee is harmonized with the Canadian Mirror Committee on ISO/TC 108/SC 4 “Human Exposure to Mechanical Vibration and Shock”, and operates in parallel with TSC 4 "Occupational Vibration Control" of the CSA Technical Committee on Occupational Hearing Conservation S304. The subcommittee continues to direct its efforts in support of the development of international standards. In this role, members of the subcommittee serve as Convenors of two Working Groups (WG5 - Biodynamic Modeling, and WG8 - Vibrotactile Perception). The most recent meeting of ISO/TC 108/SC 4 was held at Osaka, Japan, in August, 2018. Progress on documents of interest to this committee is summarized below.

1) The revision of ISO 2631-5 on the evaluation of human exposure to whole-body vibration, part 5 - method for evaluating vibration containing multiple shocks - has been published. The new standard is a complete rewrite of the previous version and so should be considered by anyone interested in the subject.
2) The revision of ISO 5982 on biodynamic models for the seated human has successfully completed the voting procedures and will be published. Both dynamic mass and transmissibility are predicted using compatible models.
3) As previously reported, the basic standard on whole-body vibration (ISO 2631-1) is being revised with the goals of updating guidance and removing inconsistencies in the current document.
4) Existing standards on the evaluation of human exposure to vibration in buildings (ISO 2631-2:2003), and the measurement and evaluation of the vibration transmissibility of gloves at the palm of the hand (ISO 10819:2013) have been reconfirmed. Canada and three other P-members voted for the revision of ISO 2631-2 and are requested to provide a working draft of a possible revision. Interested persons are asked to contact me.
5) ISO 5349-1:2001 on the measurement and evaluation of hand-transmitted vibration is to be amended to include an informative annex describing shocks entering the hand. We are invited to nominate experts. Interested persons are asked to contact me.
6) ISO 5349-2:2001, which provides practical guidance on the measurement of hand-transmitted vibration, is to be amended to include an informative annex containing a protocol on how to measure vibrations on humans. We are invited to nominate experts. Interested persons are again asked to contact me

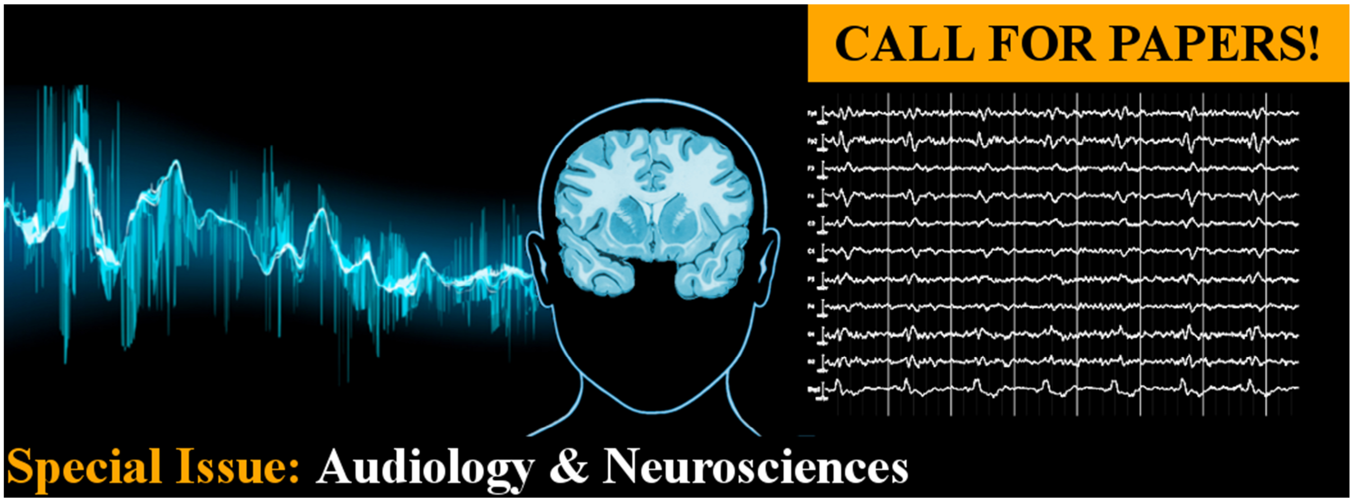
Members of the Canadian Mirror Committee: Dr. Alberto Behar (ON), Dr. Paul-Emile Boileau (Vice -Chairman, QC), Dr. Anthony Brammer (Chairman, ON), Mr. Dan Charboneau (Shoxs, BC), Dr. Tammy Eger (Laurentian University, ON), Dr. Liam Gannon (DRDC, NS), Mr. Ed Lehtinen (Impacto Protective Products, ON), Mr. Mark Lougheed (BC), Dr. Pierre Marcotte (IRSST, QC), Dr. Subhash Rakheja (Concordia University, QC), Mr. Timothy Rees (Shoxs, BC), Dr. Dan Robinson (Robinson Ergonomics, BC), Mr. John Swallow (Swallow Acoustical Consultants, ON), and Dr. Vic Schroter (MoE, ON).

A.J. Brammer
November 03, 2018

CAA Standards Committee
November 2018 Meeting
Environmental Noise Subcommittee Report

Submitted by: Bill Gastmeier, HGC Engineering

1. The Ministry of the Environment and Climate Change (MOECC) has been renamed the Ministry of Environment, Conservation and Parks (MECP) by the Ford Government
2. NPC 300 Environmental Noise Guideline - Stationary and Transportation Sources - Approval and Planning (NPC-300) has been universally implemented in Ontario. Several unresolved or somewhat controversial issues include:
   - A vacant lot zoned for a noise sensitive use must be assessed and physical noise mitigation specified if required. Implementation may be deferred until development proceeds. Location of points of reception is open to interpretation.
   - A Class 4 area allows for relaxed criteria for industrial (stationary) noise in some instances. The MOECC cannot designate Class 4 areas. That is the responsibility of the land use planning authority, developer and industry in cooperation and there is no formal process so implementation is inconsistent.
   - Assessment of impulse sound levels remains controversial and not well defined. "ISO/NP PAS 1996-3 - Acoustics -- Description, measurement and assessment of environmental noise -- Part 3: Objective Method for the Measurement of Prominence of Impulsive Sounds and for Adjustment of LAeq" is currently under review and may provide some guidance at some point.
3. Aggregate license applications typically require noise studies for licensing purposes, however these are often contested by the public. Many Municipal Official Plans now also require that noise studies done to rezone the lands for aggregate extraction and that those studies demonstrate no adverse effects (poorly defined) and some require consideration of cumulative impacts, which is difficult to do.
4. The Federation of Canadian Municipalities and the Railway Association of Canada Proximity Guidelines for New Development in Proximity to Railway Operations are now in common use.
5. CN has moved the office which provides information and reviews development applications from Toronto to Montreal and is taking a less aggressive stance than in the past. CP review function remains in Toronto.
6. There have been no new approvals for wind energy projects in Ontario and existing wind farms continue to be subject to audits.
7. No current information has been received from other jurisdictions but will be sought for our next meeting.



Acoustics is a broad subject matter that currently employs hundreds of us across Canada in fields as different as teaching, research, consulting and others. To reflect such diversity the Canadian Acoustics has been regularly publishing over the last 40 years a series of special journal issues to highlight thematic topics related to acoustics.

Therefore, the Canadian Acoustics journal is currently inviting submissions for the next special issue programmed for March 2019. **The focus of manuscripts submitted to this Special Issue may include (but are not restricted to) topics related to audiology and neurosciences such as:**

- Acoustics applications in electrophysiology (e.g. EEG, EOG, ECOG…)
- Hearing assessment (e.g. audiometry, DPOAE…)
- Any other topics in audiology/neurosciences related to acoustics.

HOW TO BE PART OF IT?

To contribute to these special "audiology and neuroscience" journal issues, authors are invited to submit their manuscript under the "Special Issue" section through the online system at http://jcaa.caa-aca.ca **before January 1st 2019**.

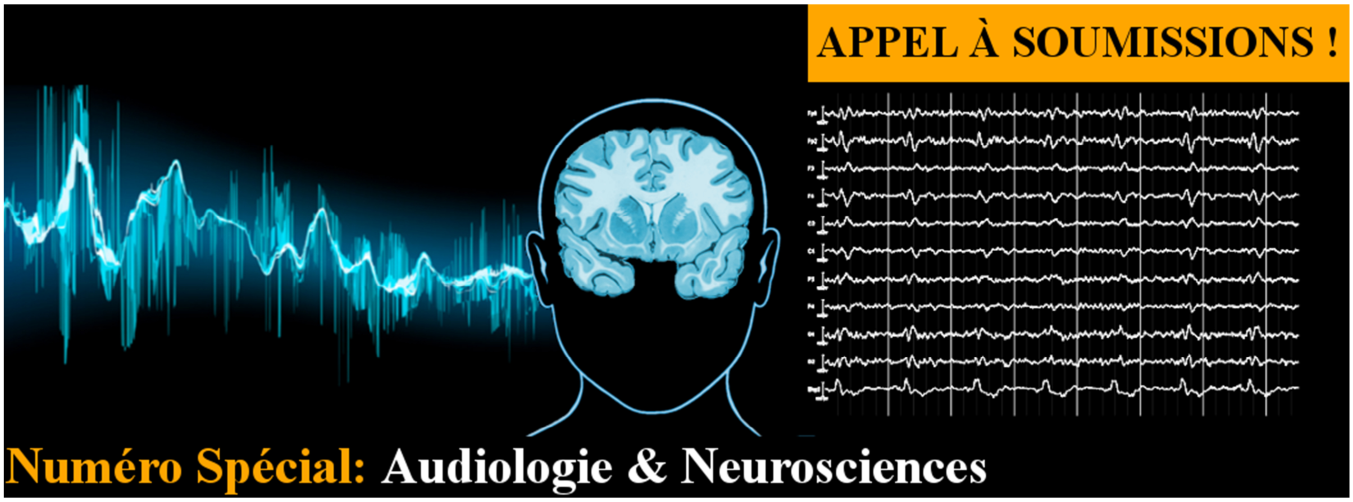
Each manuscript will be reviewed by the Canadian Acoustics Editorial Board that will enforce the journal publication policies (original content, non-commercialism, etc., refer to the Journal Policies section online for further details).

A UNIQUE SPECIAL ISSUE YOU WANT TO APPEAR IN!

This special issue of the journal can be considered as a true directory for audiology and neuroscience in Canada. They will be published in hardcopies and sent to all CAA national and international members, while electronic copies will be made available in open-access on the journal website. The content of these issues will be entirely searchable and comprehensively indexed by scholar engines as well as by major internet search engines (Google, Bing, etc.). Authors are invited to carefully select their keywords to maximize the visibility of their articles.

If you have any questions, please contact Mr. Olivier Valentin (olivier.valentin@etsmtl.ca). To secure an advertisement for this special issue, please contact Mr. Bernard Feder (advertisement@caa-aca.ca).

SUCH AN OFFER WILL ONLY APPEAR EVERY 7 OR 9 YEARS,
SO MAKE SURE TO TAKE ADVANTAGE!



L'acoustique est un vaste domaine qui offre des centaines d'emplois à travers le Canada, et ce, dans différents secteurs tels que l'éducation, la recherche, la consultation professionnelle, etc... Afin de bien refléter cette diversité, l'Acoustique Canadienne a publié régulièrement au cours des 40 dernières années une série de numéros spéciaux pour souligner les divers champs d'applications de l'acoustique

L'Acoustique Canadienne fait donc un appel à soumettre une série d'articles pour le prochain numéro spécial planifié pour mars 2019. **Ce numéro spécial inclura principalement (mais ne se limitera pas à) des contributions dont le sujet est en lien avec l'audiologie et les neurosciences, tel que :**

- Applications de l'acoustique en électrophysiologie (EEG, EOG, ECOG, etc…)
- Évaluation de l'audition et de la surdité (audiométrie, DPOAE, etc…)
- Tout autre sujet en audiologie/neurosciences en lien avec l'acoustique.

COMMENT EN FAIRE PARTIE?

Pour contribuer à ce numéro spécial « audiologie et neurosciences », les auteurs sont invités à soumettre un article, sous la rubrique « Numéro spécial » dans notre système en ligne au http://jcaa.caa-aca.ca **avant le 1er janvier 2019**. Il est possible de soumettre un même article dans les deux langues officielles.

Chaque article sera révisé par le comité éditorial de l'Acoustique canadienne qui veillera à ce que les politiques de publications de la revue soient respectées (contenu original, contenu non commercial, etc. – voir les politiques de la revue pour de plus amples détails).

UN NUMÉRO UNIQUE DANS LEQUEL VOUS VOULEZ PARAÎTRE!

Ce numéro spécial « audiologie et neurosciences » peut être considéré comme un véritable répertoire à propos de l'audiologie et des neurosciences au Canada. Ils sont publiés en format papier et envoyés à tous les membres nationaux et internationaux de l'ACA. Une version électronique est aussi disponible en ligne sur le site internet de la revue. Le contenu de ces numéros est indexé, donc facilement trouvable au moyen de moteurs de recherche classiques, tels que Google, Bing, etc… Les auteurs sont invités à bien choisir les mots clefs pour maximiser la visibilité de leur article.

Pour toutes questions, vous pouvez communiquer avec Mr. Olivier Valentin (olivier.valentin@etsmtl.ca). Pour réserver un espace de publicité dans un de ces numéros spéciaux, veuillez communiquer avec Bernard Feder (advertisement@caa-aca.ca).

UNE TELLE OPPORTUNITÉ NE SE REPRODUIRA PAS AVANT 7 OU 9 ANS,
ASSUREZ-VOUS D'EN PROFITER MAINTENANT!

7-11 july 2019

ICSV26

MONTRÉAL

26th International Congress on Sound & Vibration

The annual congress of the International Institute of Acoustics and Vibration (IIAV)

WELCOME TO ISCV26, MONTRÉAL, QC, CANADA

The International Institute of Acoustics and Vibration (IIAV) and the Canadian Acoustical Association (CAA) are pleased to invite scientists and engineers from all over the world to attend the 26th International Congress on Sound and Vibration (ICSV26) to be held in Montréal 7–11 July 2019.

This congress is a leading event in the area of acoustics and vibration and provides an important opportunity for scientists and engineers to share their latest research results and exchange ideas on theories, technologies and applications in these fields. The congress will feature a broad range of high-level technical papers from across the world: distinguished plenary lectures will present recent developments in important topics of sound and vibration and include discussions about future trends.

Montréal is an exciting, vibrating and welcoming destination. It's a city where delegates can enjoy a rich diversity of culture, museums, art galleries, night-life, gastronomy, shopping and sport, not to mention the International Jazz Festival right before the conference. Cosmopolitan Montréal offers something to suit every delegate!

THE CONGRESS VENUE: HOTEL BONAVENTURE

The congress venue will be the Hotel Bonaventure Montréal located in the heart of downtown Montréal. The Hotel Bonaventure Montréal is a true Garden of Eden overlooking the bustling streets of the city and easily connected to the underground city, central station and the business district, Old Montréal, and major attractions. A block of highly discounted rooms have been secured for ICSV26, and participants are invited to consider staying at the conference hotel to make their stay in Montréal a memorable experience! Details on accommodation at the congress venue and other hotels can be found on the ICSV26.org website.

CONGRESS SECRETARIAT ICSV26

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KEY DATES

For Registration	
Deadline for Early-Bird Registration	31 December 2018
Deadline for Early Registration	31 March 2019
Deadline for Late Registration	31 May 2019
Submission of Abstracts and Full Papers	
Abstract Deadline	1 December 2018
Deadline for Full-Length Paper Submission	31 March 2019

ORGANISED BY

International Institute of Acoustics and Vibration

In cooperation with

CANADIAN ACOUSTICAL ASSOCIATION
ASSOCIATION CANADIENNE D'ACOUSTIQUE

Jointly with

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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

ICSV26 to be held in Montreal, July 2019

The 26th International Congress on Sound and Vibration (ICSV26) will held in Montreal, Canada, from 07 - 11 July 2019 at Hotel Bonaventure.

This conference is co-sponsored by the Canadian Acoustical Association. - Deadline for abstract submission is January 31st, 2019! - - You can also check out our website at www.icsv26.org - - Jeremie Voix (conference-chair@icsv26.org) - Franck Sgard (technical-chair@icsv26.org) -

October 12th 2017

INTER-NOISE 2019 MADRID

November 30th is the deadline to submit abstracts for the Conference, don't miss the opportunity and join the INTER-NOISE Community by presenting your work in Madrid.

Important Dates: - - Abstracts Submission: Extended to December, 16th 2018. - The Manuscript Submission: March, 1st 2019. - Abstract acceptance notice will be sent to contact author by December 2018 via e-mail. - - Please contact the Congress Secretariat at internoise2019@bcocongresos.com for any questions. -

November 21st 2018

ICA 2019

The ICA 2019 congress will be held 9-13 September 2019 in Aachen, Germany. It is promising to be an interesting and exciting event. - The deadline for Abstracts is 1 February 2019. Go to http://www.ica2019.org/authors/ for the online submission. - - - -

The ICA (with the support of the Acoustical Society of America and the German Acoustical Society) has established the ICA-ASA-DEGA Young Scientist Conference Attendance Grants Programme to help young acousticians attend ICA 2019. Each grant is currently up to 500 EUR from which a portion will be used to cover the conference registration and the remainder provided at the time of the conference. Candidates must be under 35 years on the day of the opening ceremony of the Congress and may be either undergraduate or postgraduate students, postdoctoral or young acousticians. Special attention will be given to applicants from developing countries. The deadline for applications for a ICA YS Grant is 1 February 2019. Go to http://icacommission.org/YSgrants.html for more information and application forms -

January 16th 2019

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

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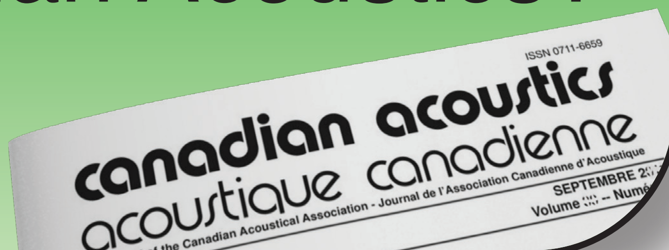

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